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Analysis and optimization of energy usage in Supermarkets

Representation and streamlining of the global supermarket energy system

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2017

Student thesis, Master degree (one year),15 HE
Energy Systems

Master Programme in Energy Systems

Master's Thesis

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Abstract

The thesis performed in this research is focused on a particular type of energy system, energy systems in supermarkets. As supermarkets are high-energy using buildings, their energy system optimization has been investigated in recent years, with the main focus in the refrigeration system, which can take up to 50% of the total energy of the supermarket. However, the complexity and interconnections of the different systems increase the difficulty of the task.

The aim of this work is to contribute in SuperSmart project, an EU project which main objective is to reduce the impact of the supermarket sector overall Europe, through the development of an ecolabel criteria. To simulate the energy use in supermarkets, CyberMart software is bring forward. This tool is used both to determine the parameters which have a higher impact in the supermarket energy system and perform energy representation based on those parameters. Finally, the design of the most energy efficient store is also presented.

According to CyberMart, some of the most determinant parameters in the supermarket energy system are refrigeration capacities, plug in cabinets used, lights power, heating system technologies used and whether the cabinets are covered or not. Using some of these parameters plus other important characteristics from the store, two energy representations are performed. The linear energy representation provides the increase or decrease of kWh per each parameter, enabling supermarkets owners to compare different parameters within the global system.

These representations, which distinguish between heat recovery and floating condensing technologies, conclude that the most important parameters in the global system are the temperature inside at winter and the refrigeration capacity. However, some unreasonable events appear, like the decline of electricity demand when the height of the building increases or the drop of heat demand with the rise of opening hours. These facts occur due to the high complexity of the global system, implying different connections between the sub-systems within CyberMart.

Concerning the most energy efficient store located in Stockholm, the obtained results show the most energy efficient supermarket is composed by CO_2 refrigeration and heating systems, and a R410_A air conditioning system. The optimal electricity use of each establishment size from large to small area is 382, 394, 390 and 281 kWh/m^2*year respectively, with the highest values obtained in Supermarkets and Discount stores, due to their higher rate of refrigeration power per store area.

Keywords: Supermarket, refrigeration system, SuperSmart, CyberMart, heating system, refrigeration capacity, plug in cabinets, lights power, heating system technology, covering of the cabinets, energy representation, heat recovery technology, floating condensing technology, air conditioning system, Discount store.

Preface

First of all, I would like to show my deepest gratitude to my supervisor, Samer Sawalha, teacher from the KTH University in Stockholm. He has shared all his knowledge with me and supported me when difficulties appeared, always being available when needed.

Secondly, I would like to thank Michele Pressiani, a research engineer in the KTH working for SuperSmart project. Together we have discussed how to proceed in many occasions, working closely and trying to find out the best path to follow.

Moreover, I would like to acknowledge Jaime Arias and Mazyar Karampour, both teachers from the KTH, without whom the development of this thesis wouldn't have been possible. Jaime is the developer of CyberMart and Mazyar provided me the required tools for the performance of the most energy efficient supermarket.

I would also like to recognize Johan Gunnarsson, working in the energy department at Willys AB. Although the accomplishment wasn't achieved, he tried to provide the necessary information to evaluate the energy representations performed in this research.

Finally, I would like to thank my parents, my sister, and my friends, for their patience and understanding, and their unconditional support during the performance of this work.

Table of Contents

Abstract 2
Preface 3
Nomenclature 7
1 Introduction 8
1.1 Background and aims 8
1.2 Literature review 9
1.3 SuperSmart Project 11
1.3.1 Objectives 11
1.3.2 Partners involved 12
1.3.3 Project paths 12
2 Energy usage in supermarkets 14
2.1 Refrigeration systems 14
2.1.1 Types of refrigeration systems 15
2.1.2 Heat recovery and floating condensing alternatives 18
2.2 HVAC system 19
3 Method 20
3.1 Most important parameters 20
3.2 Energy representation 21
3.3 Most energy-efficient Supermarket 22
4 Processes and results 23
4.1 Most important parameters results 23
4.2 Energy representation results 24
4.2.1 Quadratic equations 25
4.2.2 Linear equations and energy factors 25
4.2.3 Energy factors encompassing 31
4.3 Most energy-efficient supermarket results 32
5 Discussions 36
6 Conclusions 38
7 References 39
8 Annexes 41

Table of References

Figures

Figure 2-1. Direct system scheme.....14
Figure 2-2. Energy transfer steps in a direct system.....15
Figure 2-3. Indirect system scheme, Figure 2-4. Energy transfer steps in an indirect system.....16
Figure 2-5. Type of cascade system scheme.....17
Figure 2-6. Type of cascade system scheme.....17
Figure 2-7. Comparison of the three alternatives in three different locations for the same Hypermarket......18
Figure 2-8. HVAC system scheme.....19
Figure 4-1. Electricity use comparison between three different heat pumps for a Hypermarket in Stockholm.....33
Figure 4-2. Electricity use comparison between two different AC systems for a Hypermarket in Stockholm.....33
Figure 4-3. Energy comparison between the two cases for each establishment size.....35
Figure 4-4. Energy trends for the optimum electricity case and the primary energies for both cases.....35

Tables

Table 1-1. Nordic ecolabel criteria V3.0.....13
Table 4-1. Resume of the selected parameters for the energy representation.....24
Table 4-2. R^2 values for each regression using a heat recovery technology in Stockholm......26
Table 4-3. Energy factors resume for hypermarket and supermarket establishments using heat recovery in Stockholm......27
Table 4-4. Energy factors resume for discount and convenience establishments using heat recovery in Stockholm.....27
Table 4-5. Relative energy factors for hypermarket and supermarket establishments using heat recovery in Stockholm......28
Table 4-6. Relative energy factors for hypermarket and supermarket establishments using heat recovery in Stockholm......28
Table 4-7. Energy factors resume for hypermarket and supermarket establishments using floating condensing in Stockholm......29
Table 4-8. Energy factors resume for hypermarket and supermarket establishments using floating condensing in Stockholm......29
Table 4-9. Relative energy factors for hypermarket and supermarket establishments using floating condensing in Stockholm......30
Table 4-10. Relative energy factors for discount and convenience establishments using floating condensing in Stockholm......30
Table 4-11. Primary energy results for each establishment size.....34
Table 4-12. Electricity use for the Optimum case.....34

Equations

Equation 4-1. Quadratic equations aspect-----25
Equation 4-2. Linear equations aspect-----25
Equation 8-1. Total energy representation hypermarket in Stockholm-----61
Equation 8-2. Total energy representation supermarket in Stockholm-----61
Equation 8-3. Total energy representation discount store in Stockholm-----62
Equation 8-4. Total energy representation convenience store in Stockholm-----62
Equation 8-5. Energy factors inside the linear equations for a Hypermarket in Stockholm-----63
Equation 8-6. Energy factors inside the linear equations for a Supermarket in Stockholm-----63
Equation 8-7. Energy factors inside the linear equations for a discount store in Stockholm-----64
Equation 8-8. Energy factors inside the linear equations for a convenience store in Stockholm-----64

Annexes

Annex 8-1. CyberMart Menu 41
Annex 8-2. CyberMart climatic conditions Menu 41
Annex 8-3. CyberMart Ventilation Menu, Annex 8-4. CyberMart Heating and Air Conditioning Menu 41
Annex 8-5. CyberMart heat sources Menu 42
Annex 8-6. Monthly results for the reference Hypermarket case provided by CyberMart. 42
Annex 8-7. Hypermarket reference case data 44
Annex 8-8. Supermarket reference case data 46
Annex 8-9. Discount store reference case data 48
Annex 8-10. Convenience store reference case data 50
Annex 8-11. Results obtained with CyberMart with the Hypermarket reference data using a direct system in Spain (Barcelona). 52
Annex 8-12. Results obtained with CyberMart with the Disc Store reference data using a direct system in Stockholm. 54
Annex 8-13. Results obtained with CyberMart with the Convenience store reference data using a direct system in Stockholm 56
Annex 8-14. Quadratic equations resume for hypermarket and supermarket establishments using heat recovery in Stockholm. 57
Annex 8-15. Quadratic equations resume for discount and convenience establishments using heat recovery in Stockholm. 58
Annex 8-16. Quadratic equations resume for hypermarket and supermarket establishments using floating condensing in Stockholm. 59
Annex 8-17. Quadratic equations resume for discount and convenience establishments using floating technology in Stockholm. 60
Annex 8-18. Resume of all the equations for heat recovery refrigeration technology. 64
Annex 8-19. Hypermarket Standardized coefficients for the heating linear regression. Heat recovery technology. 65
Annex 8-20. Hypermarket Standardized coefficients for the electricity linear regression. Heat recovery technology. 65
Annex 8-21. Supermarket Standardized coefficients for the heating linear regression. Heat recovery technology. 65
Annex 8-22. Supermarket Standardized coefficients for the electricity linear regression. Heat recovery technology. 65
Annex 8-23. Disc. Store Standardized coefficients for the electricity linear regression. Heat recovery technology. 66
Annex 8-24. Disc. Store Standardized coefficients for the heating linear regression. Heat recovery technology. ..66
Annex 8-25. Conv. store Standardized coefficients for the electricity linear regression. Heat recovery technology. 66
Annex 8-26. Conv. store Standardized coefficients for the heating linear regression. Heat recovery technology. 66
Annex 8-27. Highest COP's for each energy sub-system. 68
Annex 8-28. Results using floating condensing technology and 2.5 and 1.0 as primary energy factors. 69
Annex 8-29. Results using heat recovery technology and 1.6 and 1.0 as primary energy factors. 69
Annex 8-30. Results using floating condensing technology and 1.6 and 1.0 as primary energy factors. 70

Nomenclature

HFC. Hydrofluorocarbons

DHW. Domestic hot water

AC. Air conditioning

MTS. Medium temperature system

LTS. Low temperature system

COP. Coefficient of performance

RH. Relative humidity

HVAC. Heating ventilation and air-conditioning

HR. Heat recovery

AH. Auxiliary heating

RHEX. Rotary heat exchanger

ASHP. Air source heat pump

GSHP. Ground source heat pump

1 Introduction

1.1 Background and aims

The word sustainability is becoming one of the driving forces of the world development today. However, sustainable measures are not implemented overall the world. While in Sweden several polices and measures have been implemented to reduce the greenhouse gases, countries like China produce more than half of its electricity using coal in order to maintain their low cost production chain.

Nowadays in Europe the building sector is using a quarter of the final energy consumption (European Environment Agency, 2017). Supermarkets are the most energy consumption buildings, nearly doubling the energy ratio per square meter of office buildings, and achieving high percentages of the total energy used within in country. In both the USA and France supermarkets are using a surprisingly 4% of the total energy used, while in Sweden this share drops to 3% (Sintef.no, 2017).

To achieve a reduction of these shares, firstly the expertise level of supermarket owners, manufacturers, consultants and installers should be boosted, permitting them to decide among the best energy improvement. Moreover, some barriers should be eliminated, to allow energy technological solutions to promote, and finally the sustainable awareness inside the food sector should be raised. These objectives are included inside SuperSmart, an EU project which aims to reduce the supermarket sector impact in the environment (Supersmart, 2017).

A possible way to rise the intention in reducing the supermarket impact might be providing a compensation to the establishments which achieve certain goals. To do so, both information and criteria should be provided to supermarket owners, together with some paths to verify whether they are sustainable or not. In this direction, information regarding the most important parameters within the supermarket energy system should be delivered, as well as an energy representation which would enable supermarket owners to simulate their own energy system and try to increase its efficiency.

In this representation, the refrigeration parameters and all the features they involve might play an important role. These features, as the COP of the system, should also be analyzed when representing the energy usage in supermarkets, trying to settle some limits within supermarkets energy scale. This limits would serve supermarkets owners as a guidance to know their position and become aware of their possible improvements regarding the global system.

In conclusion, supermarkets are playing an important role regarding the sustainability nowadays, not only due to their high energy use but the environmental impact their refrigerants leakages can cause. The modelling and optimization of energy use in supermarkets, which both SuperSmart project and this thesis research are trying to perform, will involve a reduction of the global energy use and an increase in both terms of global energy efficiency and sustainability.

1.2 Literature review

Since recent years, many studies have been performed to get deeper into the supermarkets energy analysis and everything it involves. However, both the variety of systems a supermarket encloses and the interconnections between them, make the global energy system a complex issue.

Lelde Timma, 2016, after the analysis of a supermarket in Latvia, concluded the greatest amount of energy use in supermarkets is due to the refrigeration systems, followed by lighting and HVAC systems. Therefore, it can be extracted that to reduce the energy use and increase the energy efficiency, refrigeration systems may take an important role.

In the same report, using a benchmarking analysis, Lelde Timma stated the specific energy amount per number of costumers has a variation of 48%. In other words, just considering the total amount of energy and the number of customers in the supermarket, the obtained results had a deviation of 48%. This means that not only the number of costumers but many other factors need to be considered when analyzing the energy use in supermarkets.

In the UK, **M.R.Braun**, 2016, analyzed seven different supermarkets to study possible energy changes in gas and electricity consumptions in relation to climate change, with the aim to predict the future energy usage in supermarkets, until 2030. As the prediction of the average future temperature was an increase of 2°C, the obtained results showed an increase in average electricity consumption of 2% and a drop in the gas usage of 10%. The understanding of this results is the following: The higher the average outdoor temperature, the lower performance of the condenser in the refrigeration systems, what results in an increase on the electricity used by the compressors. On the other hand, the higher the outdoor temperature, the lower thermal leakages of the building in winter, resulting in a reduction of both the thermal demand and consequently the gas consumption.

In the same study, local operational systems were investigated, to see the possible effect they had regarding the energy consumption. It was found that major energy users were centrally controlled. What's more, the two investigated procedures, which were the main baking time and the number of times the night covers were removed and replaced, seem to have an important role concerning the total energy consumption.

An interesting report developed by **Mylona**, 2017, built a model able to predict the hourly energy use in supermarkets with an average error of just 2 kWh. In the same study, this model was used to uncover interconnections within the global supermarket energy system. The obtained results were a surprising interdependence between the highest energy reduction (4%), and the HVAC system operating only during trading hours.

The international journal of refrigeration of **Salvador Acha**, 2016, provides a deep analysis regarding the refrigeration systems in supermarkets. From this report it can be extracted that the most relevant factors influencing the refrigeration energy demand are the connected pack load, the store opening hours and the cooling degree days.

The concrete data of the same report states a 0.94% increase on refrigeration energy use for every extra opening hour in the supermarkets. In the same direction, a 2.8% of energy rise is produced for every degree increase of the outdoor temperature. Surprisingly, no correlation between trading intensity and refrigeration energy use was found. Finally, two energy savings measures were implemented, which resulted in a surprising high reduction regarding the refrigeration energy use. By pulling down night blinds in cabinets during non-trading hours, more than 10% of energy reduction could be achieved. The second energy efficiency measure consisted on floating the suction pressure depending on the condenser performance, to achieve a reduction of the electricity demand in the compressors. With this measure, a further 7% of energy reduction was achieved.

Another important issue regarding the refrigeration systems in supermarkets is the analysis of HFC systems compared to CO_2 trans-critical systems, with the first ones as the typical solution for supermarkets in Sweden. **Samer Sawalha**, 2017, analyzed the data of three different supermarkets in Sweden, and after comparing the COP's obtained with both systems it was concluded that CO_2 systems have higher coefficient of performance than HFC systems, for outdoor temperatures lower than 24°C.

The research paper also concludes that CO_2 systems use about 20% less energy than typical HFC systems. Therefore, the analysis proves that in Sweden new CO_2 transcritical[1] systems are a more energy efficient solutions than traditional HFC systems.

Pradeep Bansal, 2012 analyzed the CO_2 as a refrigerant in low temperature systems. After a deep study of the CO_2 properties, he stated that its surface tension and density ratio were lower than other type of refrigerants, leading to a lower liquid viscosity and consequently to a smaller pressure losses of the refrigerant.

In the same report, Bansal performed a comparison between transcritical CO_2 systems and transcritical booster systems[2]. Transcritical CO_2 systems, which are used in both low and medium temperature refrigeration, use either the transcritical or the subcritical cycles depending on the temperature outdoors. Nevertheless, these type of systems are not suitable for high ambient conditions. On the other hand, transcritical booster systems in which a direct connection is placed from the low temperature to the medium temperature systems, is the most popular choice in colder climates.

Although HVAC systems have an inferior role than refrigeration systems in supermarkets, as they must assure both thermal comfort and suitable climatic conditions for the refrigeration system, they are indispensable. **Alfonso Capozzoli** performed a comparison between a traditional HVAC system and a hybrid HVAC system[3] with chemical dehumidification[4], in different Italian supermarkets.

The obtained results were large reductions of electric demand (11-17%) and supply flow rates (approx. 40%), as well as a lower value of the humidity level, which helps to food preservation. Other results to highlight are the obtained payback of just one year and the savings of 110 GWh of electric energy with a retrofitting of 30% in the implemented systems.

Liang Yang, 2010, performed a model to achieve an energy reduction opportunity of integrated HVAC and refrigeration systems. It was found that when adding both a sub cooler inside refrigeration systems and two sub coolers between HVAC and refrigeration systems, 15% energy savings were achieved for small supermarkets. The report also highlights the importance of HVAC systems, as well as their interconnections with refrigeration systems.

In order to simulate different systems solutions and possibilities regarding the energy consumption of supermarkets the software **CyberMart** was developed by **Jaime Arias**, 2006, at the Royal Institute of technology. This software has as input data climatic conditions of the area, building envelope dimensions, ventilation system features, opening hours of the store, heat sources, heating and air conditioning systems conditions and obviously refrigeration systems design (see Annex 8-1, Annex 8-2, Annex 8-5*Annex 8-3* Annex 8-5). With all these data, the software is able to simulate the energy demand in supermarkets and provide the amount of electricity and heat in the establishment. The

[1] A transcritical system includes a cycle where the fluid goes through both subcritical (below its critical point) and supercritical (above its critical point, where distinct liquid and gas does not exist) states.
[2] System where LT compressors act as boosters and discharge into the suction of the MT compressors.
[3] Systems which have two ways to produce energy, usually either via heat pump or gas furnace.
[4] Via absorption (fluid dissolved by a liquid or a solid) or adsorption (adherence to the surface of the adsorbent).

energy results obtained with CyberMart are provided either monthly or hourly, in both cases differing the energy used by different subsystems like the refrigeration system, the air conditioning system, the heating system or the lighting system, among others.

The monthly results obtained with CyberMart have the aspect shown in the Annex 8-6, with the following energy groups, differing electricity and heat: Electricity from the fans, lights, equipment, plug-in cabinets, compressors, electricity used in the A.C system and the sum of the total electricity in the refrigeration system. Regarding the heat, CyberMart provides the total heat needed to supply to the building and the part of heat used in DHW.

The hourly results are much more thorough. They provide the hourly temperatures both outside and inside, as well as the Relative humidity, the total heat demand, the part of heat supplied by the condensers in case of using heat recovery technologies and the heat needed to be delivered by AH. They also provide hourly loads for the A.C system, for the compressors, condensers and evaporators of the refrigeration system (MT and LT) and the electricity used by each subsystem. Finally, they also show the hourly condensing and evaporating temperatures.

The same study states that heating requirements can be completely satisfied with the heat released by the condenser. Nevertheless, when all the heat released by the condenser is reused, the electricity consumption of the compressors increases. According to CyberMart, the highest energy efficiency is achieved when a combined system with heat recovery and floating condensing measure is used. In this thesis the tool CyberMart will be used to try to find out the most important parameters regarding the energy use in supermarkets.

In conclusion, in this literature review many background works have been commented. Reports based on different locations as Latvia, UK or Italy have been brought forward, as well as overall energy analysis or more concrete reports focused on refrigeration and HVAC systems. In the thesis, the different sources of information will be put together to try to achieve the aim of the work: understanding and optimizing the energy use in supermarkets to reduce the environmental impact of the sector overall Europe.

1.3 SuperSmart Project

SuperSmart project is an EU project which main goal is to achieve a reduction in the environmental impact of the supermarket sector overall Europe, through an energy efficiency increase. The project aims to establish an ecolabel criteria, in order to be able to determine whether a supermarket is sustainable or not following some settled bases. In the next points, a deeper explanation of the objectives of the project is presented, as well as the partners involved and the possible paths which might take part on the project in a near future (Supersmart, 2017).

1.3.1 Objectives

The three main objectives of the project are the following (Supersmart, 2017).

- Eliminate non-technological barriers which are preventing efficient heating and cooling solutions to promote in the food retail sector. SuperSmart focuses on social, organizational and legislative obstacles which are blocking higher efficient solutions to be implemented in food retail chains.
- Increase the global expertise level for energy-friendly supermarkets, through training and promotion of the technical and non-technical staff members. A rise of knowledge would allow supermarket owners, manufacturers, consultants and installers to decide the best available refrigeration and heating technology. Nowadays, SuperSmart is providing free training lessons to spread knowledge as widely as possible.

- Support the introduction of a new EU ecolabel criteria for food retail stores. This objective consists of defining the standards which should be considered in the first phase of the label establishment. By following these criteria, supermarket owners can benefit from both reducing the energy use and being recognized as an environmental EU ecolabel establishment.

1.3.2 Partners involved

The project has 9 partners overall Europe. These partners are two technical universities, KTH from Sweden and TUBS from Germany, three national research institutes, SINTEF which is the global project leader from Norway, ITC-CNR from Italy, and CIRCE from Spain, two private corporations, Shecco from Belgium and Energija from Macedonia, one intergovernmental science and technology organization from France (IIR), and one governmental agency (UBA), from Germany.

1.3.3 Project paths

Eight different reports have been released in SuperSmart project in order to increase the acquaintance of the population not only on the project itself, but everything related to supermarkets and how they perform.

These reports present an explanation of the supermarket sector, as well as the barriers preventing food stores to become more environmentally friendly. Explanations of energy usage in supermarkets are also referenced, with a special focus on CO_2 systems, cited as innovate eco-friendly solution. Best practices of eco-friendly supermarkets overall Europe are treated in reports 3 and 4, as well as possible new technologies to be implemented and the importance of computational tools when planning the energy use in supermarkets. Finally, eco-friendly operation and maintenance are reported, with the last reports focused on everything that EU ecolabel criteria involves.

Regarding the ecolabel criteria, different existing ecolabel ways are presented in the last reports of the project, which serve as a base when developing the EU ecolabel for food retail stores. These criteria are the blue angel, the Nordic swan ecolabel, the good environmental choice and the energy star, with the first three operating in Europe and having the entire lie cycle perspective and the last one operating outside Europe and considering just the energy performance of the supermarket. Moreover, standards and legislations like ISO EN 23953-1:2015 and ISO EN 23953-2:2015 should also be considered when determining the criteria (Supersmart, 2017).

Unlike the existing criteria like Nordic ecolabel, which focus on the energy use of the different systems, the proposal for EU ecolabel distinguishes between the technical features inside the system. Depending on these features, the system gets a number of points which at the end will determine whether the supermarket is eco-friendly or not. The criteria will be divided in some mandatory requirements, which have to be accomplished and some point score requirements, which will provide points whether they are satisfied or not.

Table 1-1 shows the ecolabel criteria in NORDIC ecolabel V3.0. Stores must collect at least 23 points out of 63, with the energy efficiency providing up to 20 points. In other words, supermarkets with a good energy efficiency will almost fulfil the required points. SuperSmart uses this criteria as a starting point for the process to determine its own ecolabel criteria

Table 1-1. Nordic ecolabel criteria V3.0

Requirement	Requirement title	Max points
P1	Higher sales of organic products and products from sustainable fishing	10
P2	Higher sales of Ecolabelled consumables	10
P3	Good energy efficiency	20
P4	Little general waste	8
P5	Waste sorting	2
P6	Measures for reducing food waste	10
P7	Higher purchase of Ecolabelled consumables and services	3
Max points		63

2 Energy usage in supermarkets

While in the 19th century supermarkets used to be simple food stores with limited functions, nowadays they provide distinguished kind of services to their customers, which implies different energy-using subsystems working together as a global system. In this direction, the energy used in supermarkets is split in separated subsystems, with the interconnections between them increasing the difficulty of the global study.

The main energy-using systems in supermarkets are refrigeration systems, lighting systems, electricity used by plug in cabinets, heating systems and air conditioning systems (Timma, 2016). Of these systems, the refrigeration system can take up to 50% of the total energy use of the supermarket. Therefore, to carry out the analysis of the global system, the refrigeration system will take an important role.

Different factors and variables affect not only the performance of the refrigeration system, but consequently the global system in general. Environmental parameters like the outdoor temperature and the relative humidity indoors, have a strong impact to the refrigeration system, as they change the yield of the condenser.

In the results part a deeper explanation of these variables is presented, considering all the relevant factors affecting the global system and trying to find out which are the most significant ones regarding energy use in supermarkets. However, before that an explanation of the different subsystems is required.

2.1 Refrigeration systems

The purpose of refrigeration systems is to provide storage and food preservation to products. There are two different types of temperature levels in supermarkets, medium temperature systems, used to preserve chilled food, and low temperature systems, used to preserve frozen products. Each temperature level has two types of storages, walk-in storages, which are located inside the facilities of the supermarket and used to store the food before it is transferred to the supermarket sales area, and display cases, which store the food in the supermarket sales area, waiting for the costumers to purchase it.

Refrigeration systems basically consist of transferring heat from a cold source (displays or storages in supermarkets) to a hot source (outside), via a refrigerant moving through a closed cycle with a compression part. To understand the performance of refrigeration systems an overview of the separated components is necessary.

Figure 2-1 shows the main parts of a typical direct refrigeration system (Arias, 2006).

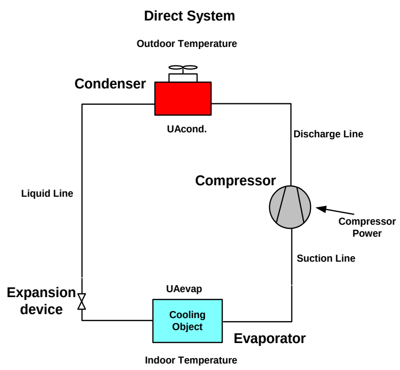

Figure 2-1. Direct system scheme

- **Evaporator:** Heat is transferred from the cabinet or storage to the evaporator, where the refrigerant temperatures varies between -15°C and 5°C for MTS and between -40°C and -30°C for LTS (Yang, 2010). As the refrigerant absorbs the heat, it evaporates.
- **Compressor:** The pressure and temperature of the refrigerant are increased in the compressor to enable the heat transfer in the condenser.
- **Condenser:** Heat is removed from the refrigerant to the outside due to the difference temperature between the refrigerant and the outside. The lower is the outdoor temperature, the better the heat flows, resulting in an improvement of the condenser performance and therefore of the global system. In this process, the refrigerant is condensed as it releases the heat absorbed in the evaporator.
- **Expansion device:** The aim of this device is to drop the pressure and temperature, before the refrigerant enters the evaporator and the cycle restarts again.

The COP of the refrigeration system defines a ratio of the cooling load provided in the cabinets to the work required in the compressors. This parameter displays the efficiency of the system and allows to quantify the performance of the system. Factors as the outdoor temperature and whether the cabinets are covered or not have a high impact on the COP of the system and therefore on the refrigeration energy (Salvador Acha, 2016).

Evaporating and condensing temperatures also affect the COP of the system, with the increase of the evaporating temperature and the decrease of the condensing temperature reducing the total energy that needs to be supplied by the compressor and consequently increasing the efficiency of the system.

2.1.1 Types of refrigeration systems

Depending on the number of steps the heat transfer takes place, as well as the type of refrigerant used, refrigeration system present distinguished forms.

Direct Systems

These are the most traditional refrigeration systems in supermarkets. In this type of systems, no intermediate steps are placed between the components. Therefore, the refrigerant circulates overall the system, from the evaporators to the condensers going through the compressors. As the condensers are commonly placed in the roof, the system requires long pipes and large refrigerant charges, to enable the refrigerant circulate from the sale floor where the displays are placed to the roof of the building.

The advantages of these type of systems are the low number of components required and their better efficiency than indirect systems, as less heat exchanges occur and consequently less heat is lost. On the other hand, as refrigerant charges are bigger, more refrigerant leakages appear and as a result the harming to the environment rises.

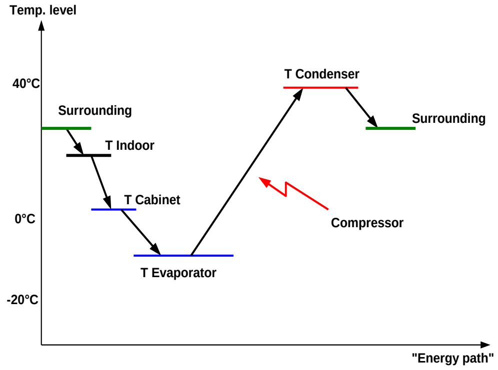

Figure 2-2. Energy transfer steps in a direct system

Figure 2-1 shows an overall scheme of this type of systems, whereas Figure 2-2 shows the steps that take place in the process (Arias, 2006). The total number of steps is lower than any other system.

Indirect systems

Unlike direct systems, indirect systems perform the exchange of heat within different steps and circuits. Heat is transferred from the cabinets to the chillers[5], which contain a direct system, through the evaporator secondary system[6]. After the direct system in the chillers is completed, the heat is transferred to the outside through the condenser secondary system[7]. Therefore, in completely indirect systems, two independent circuit loops apart from the chiller are placed, with different filled fluids which fit the required properties to boost the efficiency. Nowadays, CO_2 is commonly used as a secondary refrigerant.

The advantage of this type of systems is the less refrigerant charge required and consequently the less impact to the environment. On the other hand, the energy use is supposed to be increased due to the reduction of the efficiency caused by the increase of heat exchanges. Nevertheless, recent studies have concluded that in some situations indirect systems can present better performance than indirect ones.

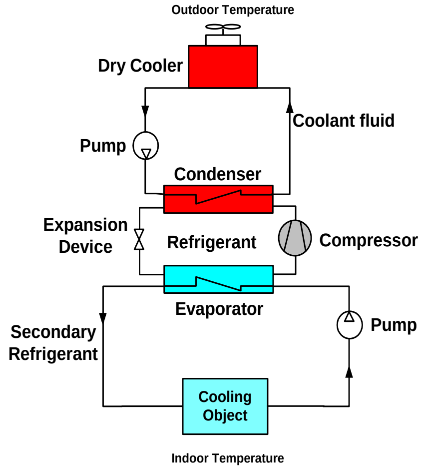

Figure 2-3. Indirect system scheme

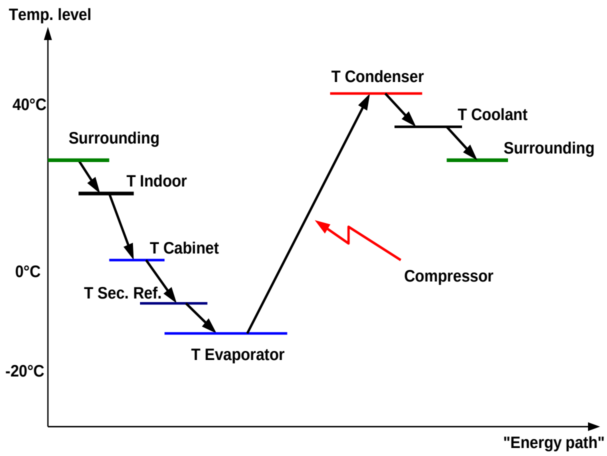

Figure 2-4. Energy transfer steps in an indirect system

Figure 2-3 and Figure 2-4 (Arias, 2006), represent respectively an indirect system scheme and the different temperature steps done in the process. As Figure 2-3 shows, the number of steps has increased in comparison to direct systems.

Cascade systems

In these type of systems LTS and MTS are thermally coupled by a heat exchanger, which acts as an evaporator for the MTS and as a condenser for the LTS. In other words, the heat released by the condenser of the LTS is picked by the MTS, with the condensation heat of the LTS being equal to the evaporating heat of the MTS.

[5] Machine that removes heat from a liquid for refrigeration purposes.
[6] The system which transfers heat from the cabinet to the chiller is referenced as the evaporator secondary system.
[7] The system which transfers heat from the chiller to the outside is referenced as the condenser secondary system.

Therefore, these systems have different circuits coming from the displays for each temperature level, but they are coupled afterwards, with just one circuit loop releasing the heat outside. Figure 2-5 and Figure 2-6 show two different variants which these type of systems may adopt (Arias, 2006).

The advantage of this type of system is that it avoids large pressure ratios in the low temperature system. On the other hand, the compressor power of the MTS is increased due to the heat rejected from the condenser of the LTS.

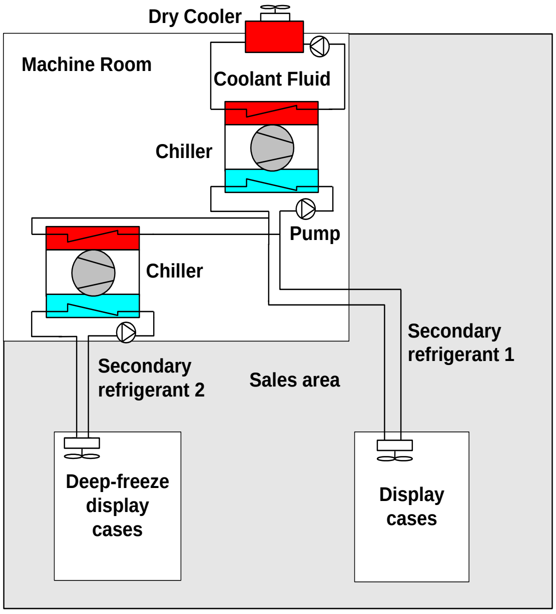

Figure 2-6. Type of cascade system scheme

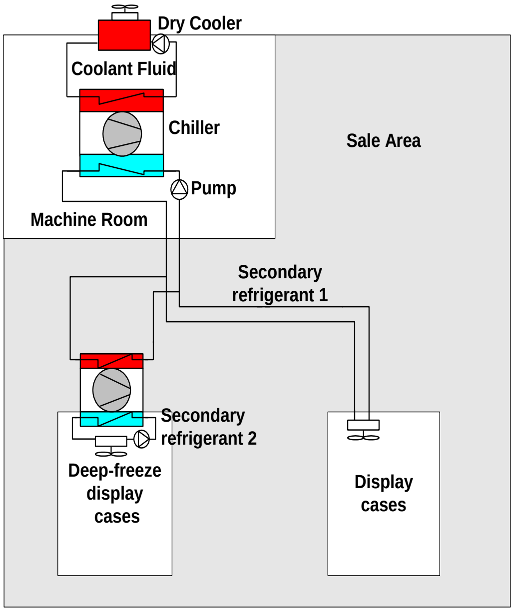

Figure 2-5. Type of cascade system scheme

Carbon dioxide systems

CO_2 is commonly used in both cascade and indirect refrigeration applications, used in the low temperature stage due to the ability to reduce the condensation pressure, which results in less power delivered by the pump. Its great thermophysical properties at low temperatures such as high vaporization enthalpy and vapor density, allows subcritical refrigeration systems[8] to reach high COP's, especially thank to the great heat transfer performance inside both the condenser and evaporator (Bansal, 2012).

Other CO_2 applications are in transcritical systems, which deal just with one refrigerant and can be used in direct expansions for both low and medium temperatures. These systems are quite simple, and in Sweden their performance is much better than the traditional HFC systems, with higher total COP's and less energy use (Sawalha, 2017).

Moreover, the odorless, nontoxic and non-flammable properties make it suitable for the food industry and food stores. The environmental impact of this type of systems is lower than other systems with different type of refrigerants. However, their drawbacks are the high operating pressure of the higher part of the cycle and in the case to be used in indirect or cascade systems both the probability to decrease the energy efficiency of direct systems and the complex electronic control system they involve (Bansal, 2012).

[8] Refrigeration systems where the fluid works below its critical point

Considering their better performance in both indirect and direct systems, the use of CO_2 systems is expected to be increased in the future (Sawalha, 2017 and Bansal, 2012).

2.1.2 Heat recovery and floating condensing alternatives

Both heat recovery and floating condensing alternatives have the aim to reduce the global energy demand of the supermarket by increasing its efficiency, through improvements in the refrigeration system. The use of these two alternatives is increasing in the food stores world nowadays.

Heat recovery improvements basically consists of taking profit from the heat released by the condenser. In other words, the heat rejected by the condensers is used in a heat exchanger to heat air and therefore reduce the energy demand that the auxiliary heating system needs to supply to ensure the desired indoor air temperature.

The amount of heat released in the condensers would be enough to cover all the heating demand of the building (Arias, 2006). However, the more heat is recovered in the condensers, the more electricity use of the compressors, resulting in an increase of the costs of the refrigeration system. Therefore, an optimization is required to achieve the lowest cost as possible. Normally, from 40% up to 70% of the total heating demand of the building can be covered with the heat rejected from the condensers, when this type of alternative is installed (Sawalha, 2013).

On the other hand, floating condensing alternatives are focused in reducing the electricity consumption of the compressors. In these type of systems, the condensing temperature changes with the ambient temperature, what results in different working pressures and therefore different power consumptions of the compressors. When the outside temperatures are relatively low, the performance of the condenser increases, resulting in less pressure rate supplied by the compressors and consequently an increase of the COP of the system.

Moreover, some systems have been designed in Sweden with both systems working simultaneously. These coupled systems allow the refrigeration system to work with low condensing temperatures when the heating demand drops, resulting in a reduction of the global energy use of the system. Figure 2-7, performed using CyberMart software, shows a comparison between the three different possibilities in three distinguished locations. As the figure shows, the combination of the two alternatives is the best general option, with the lowest energy demand in the three locations.

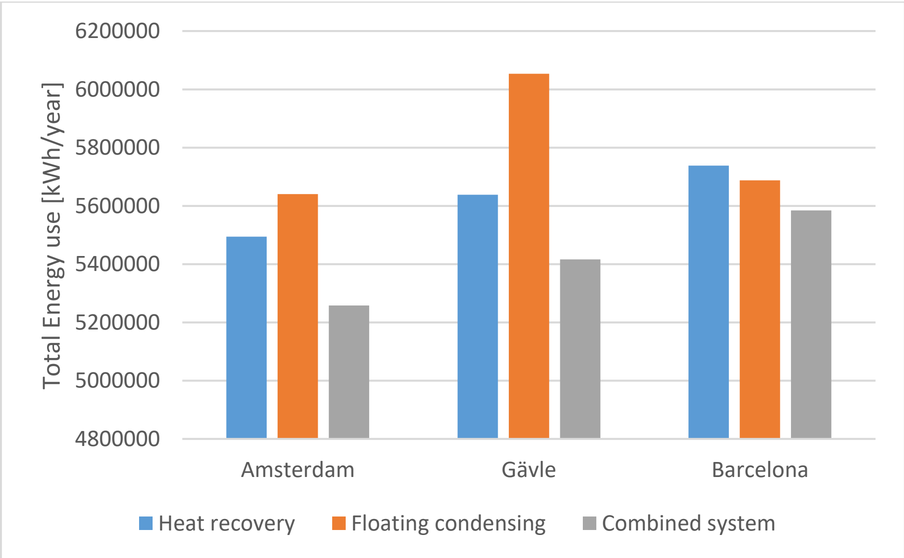

Figure 2-7. Comparison of the three alternatives in three different locations for the same Hypermarket.

Hypermarket data. Area: 8000 m^2, 379kW of M.T refrigeration capacity, 69kW of L.T refrigeration capacity

2.2 HVAC system

The heating, ventilation and air conditioning system has the aim to ensure the properly air quality and provide thermal comfort to all the people inside the establishment. Considering the well-being of the costumers might affect their volume of purchase, this system may have direct impact to the sales of the store.

The interlinked heat exchanges between the building, HVAC and refrigeration systems increase the complexity of the system, with the necessity to study the system in a global way. In this direction, possible implementations like adding multiple sub coolers both inside refrigeration systems and between HVAC and refrigeration systems can achieve savings of 15% (Yang, 2010). Moreover, it has been found that HVAC systems have a strong connection with the total energy used in a supermarket, with the highest energy reduction achieved when HVAC systems are operating only during trading hours (Mylona, 2017).

Figure 2-8 shows the scheme of a typical HVAC system for a supermarket (Arias, 2006). In the figure, the fresh air from outside (estate 1) goes through a heat exchanger, which transfers heat from the air flow leaving the building (estate 7) to the one reaching the establishment. Some of the leaving air, however, doesn't reach the heat exchanger as it is recirculated and mixed with the air outgoing the heat exchanger, with the mixture of airs encompassed in state 3. The amount of air that can be recirculated depends on the required quality indoors. In case no heating inside the building is required, the heat exchanger is not working and therefore states 1 and 2 are the same.

An air fan is placed between states 3 and 4, in order to ensure the air flow. After state 4, the air is either heated or cooled depending on the requirements of the building. The cooling of the air in the AC section, can either be provided with district cooling or chillers. On the other hand, the heating occurs in two different steps, the HR section, where the heat rejected from the condensers is used, and the AH section, where the rest of heat to ensure the required indoors properties is provided. This heat can be supplied via district heating or boilers among others, with the first option the most common option in Sweden.

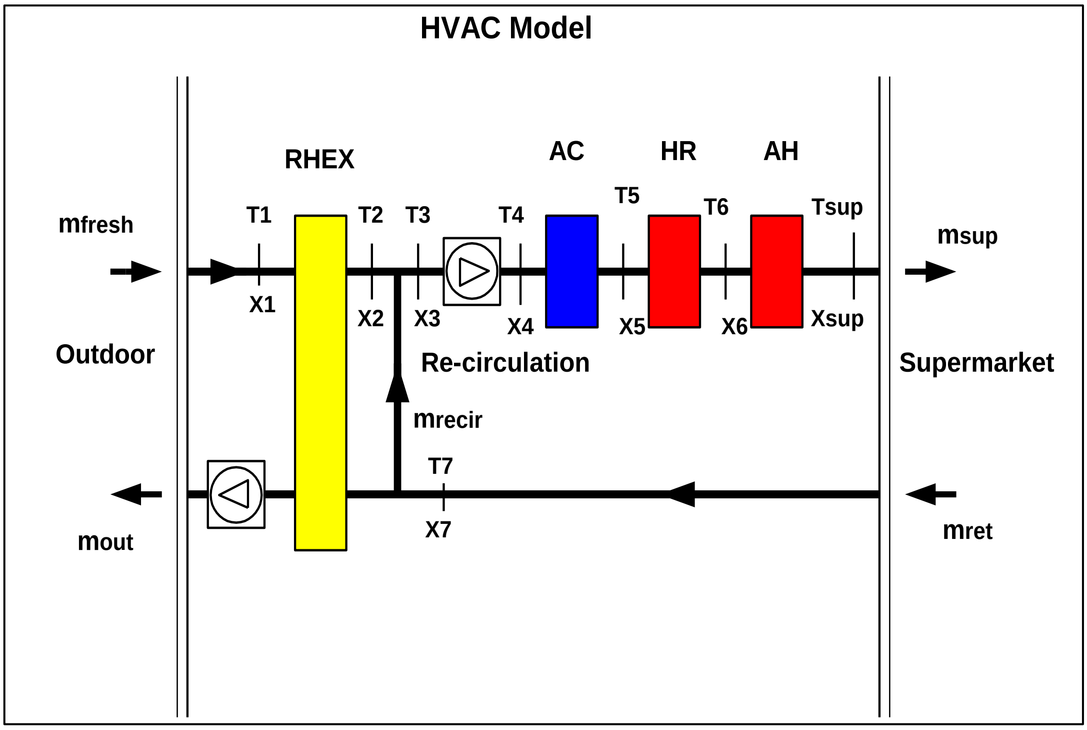

Figure 2-8. HVAC system scheme

3 Method

Taking a closer look at the different objectives of SuperSmart, it is easy to become aware of their high generality. In other words, to proceed with the performance of the project some previous goals need to be defined. Thus, these goals will always have in mind both to increase the global knowledge of energy-friendly supermarkets and to get closer to the development of the EU ecolabel criteria. All the required simulations to try to achieve these objectives have been performed with CyberMart software, while in the data analysis XLSTAT software working together with Excel is used.

Before to expose the different goals, it is important to highlight the conditions in which the simulations have been simulated. As SuperSmart is a European project, some simulations have been carried out in two representative European locations, Stockholm and Barcelona. However, some goals are focused in a specific location, Stockholm, in order to reduce the amount of work and the width of the results. Finally, the food stores are divided in four distinguished groups, depending on their dimensions. These groups are, from smaller to bigger areas, *Convenience Store*, *Discount Store*, *Supermarket* and *Hypermarket*.

A reference case for each group is stablished (see Annex 8-7 until Annex 8-10), which are based on real stores. Important data to highlight in these reference cases are the use of district heating and chillers for heating and cooling purposes, as well as the use of HFC refrigerants in all refrigeration systems. Concerning the refrigeration system type, Hypermarket and Supermarkets references use a completely indirect system, while the two others contain a direct one. Finally, all references but Convenience stores are using heat recovery technology. Convenience stores don't use neither heat recovery nor floating condensing technologies, due to their low energy use, which doesn't make these investments profitable.

3.1 Most important parameters

The first proposed goal is to find out the main parameters which have a higher impact in the final energy use of the supermarket. To identify these parameters, simulations concerning many different input factors are performed. These factors are changed one by one, with always just one value differing from the reference case, either above or below the benchmark. The location is also changed to achieve global parameters which can be used overall Europe.

Although the results presented in CyberMart are monthly, with each month providing two different values, heat and electricity, the values used to select the most important parameters are annual and englobing the total energy of the supermarket, which is calculated summing the annual electricity and heat. The main reason of this simplification is a reduction of the obtained results. In other words, the simulations could distinguish between electricity and heat, as well as they could distinguish between different locations overall Europe or even between different months of the year. It is needless to say that the amount of data would be too high.

Energy changes resulted in each simulation can be assigned to the parameter shift, with all the others remaining as the reference. In this way, the variation of the total energy concerning the reference case can be obtained, and as each energy change is linked to a parameter variation, the parameters which have a higher effect in the global energy of the supermarket are founded.

Nevertheless, as the parameters are simply changed one by one from the reference case, always just one parameter is differing from the reference. Consequently, this method is neglecting the interaction between the different factors within the different systems of the supermarket. In other words, it might be many combinations of settings which achieve a higher or lower energy use that are not analyzed.

On the other hand, there are implementations which decrease the energy use of one part of the energy system but they increase another. As an example, the implementation of a heat exchanger using the energy released by the condenser will reduce the heat demand of the supermarket, but could increase the electricity consumption of the compressors in the refrigeration system. In other words, the results obtained with this procedure have a lack of information, what means they should be complemented with other sources coming from distinguished paths.

In conclusion, in this part the method to find out the most important parameters of the supermarket energy system is presented, however, to understand the global system other sources of information are required. As the results part present, the number of selected parameters is fourteen.

3.2 Energy representation

In this direction, the next goal is to define a way that represents the energy used in Supermarkets without the necessity to use CyberMart, and with the ability to perform the interaction and combination of the parameters within the system. This way, should be able to predict the energy used in the store, considering different input factors of it. To perform this representation, the most important parameters within the supermarket are used due to the impossibility to consider all the factors.

Therefore, in this step the information extracted from the previous part is used. After selecting the fourteen most important parameters, quadratic energy equations per each establishment size are obtained, equations which have as input parameters the fourteen selected factors. In other words, the most important parameters of the supermarket are used as variables to achieve the equations that will be part of the energy representation. Per each establishment size, two different equations are performed, one for electricity and one for heat.

To achieve these equations new simulations are required. These new simulations, however, only involve the fourteen chosen factors, as they will be the only ones presented in the equation. Per each of the fourteen parameters, four or five different values are selected, above or below the reference case. Similarly to the first simulations, whenever a parameter is changed all the others are keep in the reference values. In order to reduce both the amount of work and obtained results, the selected location is Stockholm, in which the 4 different establishment sizes are simulated.

In this way, the factor's change is related to the energy change, what allows the software XLSTAT to create the representative equations for the energy of the food store. The quadratic obtained equations have a high accuracy, achieving errors lower than 2% with regards to the results obtained with CyberMart.

Considering the total equation obtained, each of the fourteen parameters have a term inside the equation referred to itself. Each of these terms have the form: $a_i X^2 + b_i X + cte$, where X is the value of the parameter in the store and "a_i" and "b_i" are the constant factors of the equation. Depending on the parameter, factors "a_i" and "b_i" have different signs, with these signs and values containing challenging mathematical meanings. In other words, these equations are quite long and complex.

In the direction of the above, to complement the quadratic energy representation a linear representation is performed not only to provide the information in a more clarify way, but to be able to compare different terms of each parameter inside the equation. Therefore, with the same new simulations used for the quadratic equations, linear equations are obtained, with each of the terms of the equations presenting the form: $a_i X + cte$. Similarly as before, each of these terms is associated to one of the fourteen parameters. From now on, the factors a_i are referenced as energy factors.

These energy factors, which are also obtained with XLSTAT, give the slope of the line obtained from the total energy of the supermarket concerning the stated factor. In other words, in a graph representing the total energy of the supermarket depending on just one of the fourteen parameters, the value of the energy factor of that parameter would be the slope of the line obtained.

Furthermore, each factor of the equation has a real meaning on the supermarkets energy use, giving the annual increase or decrease in kWh of the energy used per unit of factor. Nevertheless, as the comments in the results part clarify, the meaning of some values is also challenging to understand.

Although in all the electricity equations the errors are quite low, the main drawback of this method is the accuracy, which drops considerably concerning the quadratic equations. The error pairing with heat energy factors is highly increased, reaching too high values when representing the energy for an establishment. Therefore, the main ideas of these factors are both to clarify the information from the equation and enable the possibility to compare different energy terms, but when a high precision is needed they will need to go together with the quadratic equation.

In conclusion, this energy representation allows supermarkets owners to rapidly simulate their own energy system, highly increasing their knowledge of the system and permitting a potential energy reduction based on fourteen selected parameters.

3.3 Most energy-efficient Supermarket

The final goal presented in the work is the design of the most energy efficient supermarket possible, both used to reveal the real position of the establishment within the food stores scale and to know how much energy improvement can still be achieved. The selected location is Stockholm.

To design the highest energy-efficient supermarket, the maximum energy efficiency possible has to be implemented into the establishment, or in other words, all different sub-systems inside the supermarket energy use have to operate with their highest COP's. However, the study will focus on refrigeration, heating and cooling systems, with other energy using systems like lights, connected equipment, plug in cabinets and fans not included in the optimization. In other words, the electricity used by these systems is considered constant with regards to CyberMart values.

In the direction of the above, the first required data is the largest potential COP's for each of the three stated systems. Once these highest COP's are obtained, a way to apply them inside the three systems is demanded. To do so, the energy loads that each system needs to supply is necessary, so that dividing the energy load by the highest COP, the lowest electricity used is achieved. These annual energy loads are the heating supplied by the heating system (after the heat from the condensers is used), the cooling demand of the establishment supplied by the AC system and the sum of the cooling demand in all the cabinets, or in other words the heat that the evaporators need to extract from the cabinets.

The COP's of each system have a strong dependence on the temperature outside, which implies the study to be performed per hour always considering the temperature fluctuations. As literature review part concludes, CyberMart provides hourly energy loads, for both heating and cooling purposes inside the establishment, as well as the for the proper use of the refrigeration system (MT and LT).

Therefore, considering the temperature outside, for each hour of the year the COP's, the energy loads and the lowest energy input for each of the three systems are obtained. Thus, the lowest energy using establishment or the most energy-efficient supermarket is obtained. Nevertheless, a previous step is required, concerning a comparison between different heating and AC systems, in order to find out which is the best option per each subsystem (see results part).

4 Processes and results

In this part all the obtained results following the method are presented. As it is highlighted in the method part, all the simulations are performed with CyberMart. To create the quadratic equation and the energy factors, XLSTAT software integrated in Excel is used.

4.1 Most important parameters results

In order to find out the parameters which have a higher impact in the global energy use in food stores, changes regarding the following parameters are applied: walls, walls integration, height, windows, windows area, air change, entrance air, ventilation, lights, occupants, covers, refrigeration technology, indoor temperature for both summer and winter, plug in electricity used for low and medium temperatures and refrigeration capacities for low and medium temperature. The area is not included as it is the parameter distinguishing different establishments sizes.

Annex 8-11, Annex 8-12 and Annex 8-13 show the results obtained with different store size in distinguished European locations. Concretely, the simulations are performed in Barcelona for Hypermarket reference cases, and in Stockholm for both discount and convenience reference cases, always obtaining monthly results from CyberMart. These tables provide information regarding the energy percentage change from the reference case, and it is the criteria to order the rows of the table.

From these tables it can be extracted that some of the most important parameters in supermarkets are refrigeration technologies, lights, refrigeration capacities, plug in cabinets, whether the cabinets are covered or not, ventilation technologies, winter temperatures inside and wall features. Other factors are the air change rate, the number of occupants and the summer temperature inside.

However, in order to understand the real effect of these factors to the supermarket energy system, a deeper analysis is required.

4.2 Energy representation results

Taking a look to the most important parameters presented in last chapter, it can be concluded that many of them are referenced to the refrigeration system. This means that factors representing the building features or the time when the supermarket is opened are not included in the list of the most important parameters.

In this context, the concept of generality appears, resulting in not only refrigeration parameters included in the representation, but also parameters from other systems and sources. Moreover, the more focused a general representation is, the more risks are taken. In other words, in the case some problems appeared with the refrigeration system representation this will highly impact on the global representation, while in a more distributed representation this might not occur.

Therefore, the fourteen selected parameters to build the energy representation try to represent the supermarket in a general way. Table 4-1 shows these parameters, with the absence of the lights, the refrigeration technology and the cover of the cabinets.

Table 4-1. Resume of the selected parameters for the energy representation

Parameter	Units
Sales area	m^2
Height of the building	m
Temperature inside winter	°C
Temperature inside summer	°C
Opening hours	h
Plug in electricity MT	W
Plug in electricity LT	W
Cabinets group 1	Number of Cabinets of 1875 W for M.T
Cabinets group 2	Number of Cabinets of 2500 W for M.T
Cabinets group 3	Number of Cabinets of 3750 W for M.T
Cabinets group 4	Number of Cabinets of 1975 W for L.T
Cabinets group 5	Number of Cabinets of 2500 W for L.T
Cabinets group 6	Number of Cabinets of 3750 W for L.T
Volume flow	m^3/h

Considering the high impact of the refrigeration technology, an energy representation for each heat recovery and floating condensing technologies will be obtained. Therefore, the refrigeration technology will not be a parameter inside the equation, but a factor which will determine which equation to use.

Concerning the lights and the covering of the cabinets, they are considered invariable from the reference case. The reason of these considerations are the progress of the stores with regards to this parameters, which in a near future might be as the reference e.g. the lighting system should be efficient and all the cabinets should be covered. In other words, there will be no sense to study the sustainability of a supermarket in which these two parameters differ from the reference.

Furthermore, as the method part concludes, two different type of equations will be performed, the quadratic and more accurate one, but with a less meaning level, and the linear and more clarify one but with a less accuracy level, which contains the referenced energy factors. The results are showed in the two following sections, always distinguishing between electricity and heat.

4.2.1 Quadratic equations

In this section, the quadratic equations are presented. These equations represent the electricity and heat use of the building, based on the parameters from Table 4-1, and they have the following aspect.

Equation 4-1. Quadratic equations aspect

$$Annual\ Heat\ or\ Electricity\ [kWh] = \sum_i a_i {X_i}^2 +\ b_i X_i + cte$$

Where X_i is the value of each parameter from Table 4-1, a_i and b_i the different terms of the equation multiplying the parameters and *cte* the constant value of the equation.

Annex 8-14, Annex 8-15, Annex 8-16 and Annex 8-17 resume the different quadratic equations obtained for each establishment size. The main advantage of this equations is their high accuracy, with errors going between 0.03 to 1.8%. The lower the establishment energy use, the higher this error becomes, with always heat equations involving a higher error share than the electric ones.

Nevertheless, as the method part states, terms a_i and b_i presented above have challenging mathematical meanings, what implies the use of these equations to be limited to their final results. Moreover, no comparisons concerning the contributions of each parameter to the total equation are allowed, at least in a general way.

Therefore, although their high accuracy, these equations will only be used to get the final energy use of the establishment, and not to compare the strength of each parameter. The change in the total energy concerning the change of each parameter is not included either, information which is provided in the following part of the project, where the concept of energy factors appears.

4.2.2 Linear equations and energy factors

The term of energy factor implies the heat or electricity variation related to each parameter change. Each parameter has two associated energy factors, one for electricity and one for heat, which are founded inside a linear equation with the following aspect.

Equation 4-2. Linear equations aspect

$$Annual\ Heat\ or\ Electricity\ [kWh] = \sum_i Energy\ Factor_i X_i + cte$$

Therefore, each energy factor is providing the increase of kWh per unit of parameter and per year. Table 4-3 and Table 4-4 show these parameters for a heat recovery technology in the refrigeration system, whereas Table 4-7 and Table 4-8 show the energy factors for a floating condensing technology. In these tables, negative values are emphasized. Annex 8-18 presents the heat recovery equations in a complete manner. From Annex 8-19 until Annex 8-26, the standard coefficients of the linear regression are presented, in a graphical way.

Table 4-5, Table 4-6, Table 4-9 and Table 4-10 show the energy factors in a relative way. To obtain these values, the numerical energy factors are divided by either the total electricity use or the total heat use of the establishment, respectively. These relative energy factors, give the percentage of energy change per unit of parameter variation, and their tables contain a conditional formatting for each energy type, where the green cells contain the higher values and the red cells the lower ones.

However, in some cases the errors coming with these energy factors reach too high values, especially in the heat case. Therefore, supermarkets owners should know the situations and conditions to use them. After the eight tables are presented, comments regarding some surprising results for different parameters and establishments are presented, as well as possible ways to use the factors.

Taking a look to the R-squared parameters [9] of the regressions, which are also provided by XLSTAT software, in all cases but the heat regressions for discount store the R^2 values are higher than 90%. Table 4-2 presents these values for a heat recovery technology in Stockholm.

R^2	**Hypermarket**		**Supermarket**		**Disc. Store**		**Conv. Store**	
	Electricity	Heat	Electricity	Heat	Electricity	Heat	Electricity	Heat
Linear Regression	0,991	0,900	0,938	0,957	0,988	0,283	0,993	0,994
Quadratic Regression	0,998	1,000	0,995	1,000	0,997	0,657	0,996	0,999

Table 4-2. R^2 values for each regression using a heat recovery technology in Stockholm.

[9] R-squared is a statistical measure of how close the data is to the fitted regression line. It is also known as the coefficient of determination, or the coefficient of multiple determination for multiple regression. In general, the higher the R-squared, the better the model fits your data, however, R-squared does not indicate whether a regression model is adequate, it indicates its variance.

Table 4-3. Energy factors resume for hypermarket and supermarket establishments using heat recovery in Stockholm.

Heat Recovery	Hypermarket		Supermarket	
Energy Factors	**Electricity**	**Heat**	**Electricity**	**Heat**
*Area (kWh/m2*year)*	132.2	24.3	116.0	7.3
*Height (kWh/m*year)*	-6045.7	47238.7	-1310.1	31919.9
*T_{in} winter (kWh/°C*year)*	29939.0	112438.1	19433.3	45613.5
*T_{in} Summer (kWh/°C*year)*	5159.0	2272.5	252.6	-718.3
*Plug in MT (kWh/Cabinet*year)[10]*	17677.8	-3594.2	19923.5	-8759.1
*Plug in LT (kWh/Cabinet*year)[11]*	20747.9	-4316.6	22960.2	-10569.0
*Opening hours (kWh/h*year)*	311.7	-16.9	97.7	-41.9
*Group 1 (kWh/Cabinet*year)*	4719.5	1675.8	7528.2	4729.9
*Group 2 (kWh/Cabinet*year)*	5605.7	1938.9	8533.7	5352.4
*Group 3 (kWh/Cabinet*year)*	11760.8	3884.6	13351.5	9496.3
*Group 4 (kWh/Cabinet*year)*	3804.0	300.3	3047.8	1513.6
*Group 5 (kWh/Cabinet*year)*	9082.8	1232.2	8498.3	3794.0
*Group 6 (kWh/Cabinet*year)*	13947.2	2080.0	12360.7	5680.7
*Volume flow(kWh/(m3/h)*year)*	18.1	-3.2	17.6	-5.9
Constant	-2361084.6	-2568264.4	-1028965.4	-867503.1
Error (%)	0.18%	2.98%	0.65%	3.97%

Table 4-4. Energy factors resume for discount and convenience establishments using heat recovery in Stockholm

Heat Recovery	Discount Store		Convenience Store	
Energy Factors	**Electricity**	**Heat**	**Electricity**	**Heat**
*Area (kWh/m2*year)*	108.9	-0.6	48.1	30.6
*Height (kWh/m*year)*	-807.8	-32.7	-615.3	714.6
*T_{in} winter (kWh/°C*year)*	5439.5	170.5	550.6	1765.2
*T_{in} Summer (kWh/°C*year)*	568.9	28.5	315.0	50.2
*Plug in MT (kWh/Cabinet*year)[10]*	13933.4	-133.8	12183.2	-6692.9
*Plug in LT (kWh/Cabinet*year)[11]*	17550.1	-114.2	17983.1	-8395.1
*Opening hours (kWh/h*year)*	21.7	-0.7	2.0	0.3
*Group 1 (kWh/Cabinet*year)*	3825.2	-32.2	3108.7	3436.6
*Group 2 (kWh/Cabinet*year)*	4512.1	-50.6	4158.1	3799.1
*Group 3 (kWh/Cabinet*year)*	7733.9	9.6	6538.0	7460.3
*Group 4 (kWh/Cabinet*year)*	3191.6	-50.3	2888.6	1237.8
*Group 5 (kWh/Cabinet*year)*	8516.3	-8.5	7177.3	3358.2
*Group 6 (kWh/Cabinet*year)*	12489.0	267.5	10736.8	5262.5
*Volume flow(kWh/(m3/h)*year)*	24.0	-1.2	12.6	-1.8
Constant	-189750.9	26803.5	-9170.7	-32254.9
Error (%)	0.27%	1.62%	1.00%	5.97%

[10] Power of the cabinet considered for MT: 2000 W
[11] Power of the cabinet considered for LT: 2000 W

Table 4-5. Relative energy factors for hypermarket and supermarket establishments using heat recovery in Stockholm.

Heat Recovery	Hypermarket		Supermarket	
Energy Factors	**Electricity**	**Heat**	**Electricity**	**Heat**
*Area (kWh/m2*year)*	0,003%	0,010%	0,007%	0,004%
*Height (kWh/m*year)*	-0,124%	18,533%	-0,082%	18,364%
*T_{in} winter (kWh/°C*year)*	0,616%	44,112%	1,220%	26,242%
*T_{in} Summer (kWh/°C*year)*	0,106%	0,892%	0,016%	-0,413%
*Plug in MT (kWh/Cabinet*year)*	0,364%	-1,410%	1,251%	-5,039%
*Plug in LT (kWh/Cabinet*year)*	0,427%	-1,693%	1,442%	-6,080%
*Opening hours (kWh/h*year)*	0,006%	-0,007%	0,006%	-0,024%
*Group 1 (kWh/Cabinet*year)*	0,097%	0,657%	0,473%	2,721%
*Group 2 (kWh/Cabinet*year)*	0,115%	0,761%	0,536%	3,079%
*Group 3 (kWh/Cabinet*year)*	0,242%	1,524%	0,838%	5,463%
*Group 4 (kWh/Cabinet*year)*	0,078%	0,118%	0,191%	0,871%
*Group 5 (kWh/Cabinet*year)*	0,187%	0,483%	0,534%	2,183%
*Group 6 (kWh/Cabinet*year)*	0,287%	0,816%	0,776%	3,268%
*Volume flow(kWh/(m3/h)*year)*	0,000%	-0,001%	0,001%	-0,003%

Table 4-6. Relative energy factors for hypermarket and supermarket establishments using heat recovery in Stockholm.

Heat Recovery	Discount Store		Convenience Store	
Energy Factors	**Electricity**	**Heat**	**Electricity**	**Heat**
*Area (kWh/m2*year)*	0,026%	-0,003%	0,068%	0,384%
*Height (kWh/m*year)*	-0,191%	-0,166%	-0,871%	8,977%
*T_{in} winter (kWh/°C*year)*	1,289%	0,868%	0,780%	22,174%
*T_{in} Summer (kWh/°C*year)*	0,135%	0,145%	0,446%	0,630%
*Plug in MT (kWh/Cabinet*year)*	3,303%	-0,681%	17,252%	-84,072%
*Plug in LT (kWh/Cabinet*year)*	4,160%	-0,581%	25,466%	-105,454%
*Opening hours (kWh/h*year)*	0,005%	-0,003%	0,003%	0,004%
*Group 1 (kWh/Cabinet*year)*	0,907%	-0,164%	4,402%	43,168%
*Group 2 (kWh/Cabinet*year)*	1,070%	-0,257%	5,888%	47,722%
*Group 3 (kWh/Cabinet*year)*	1,833%	0,049%	9,258%	93,711%
*Group 4 (kWh/Cabinet*year)*	0,757%	-0,256%	4,090%	15,548%
*Group 5 (kWh/Cabinet*year)*	2,019%	-0,043%	10,164%	42,183%
*Group 6 (kWh/Cabinet*year)*	2,961%	1,361%	15,204%	66,104%
*Volume flow(kWh/(m3/h)*year)*	0,006%	-0,006%	0,018%	-0,023%

Table 4-7. Energy factors resume for hypermarket and supermarket establishments using floating condensing in Stockholm.

Floating Condensing	Hypermarket		Supermarket	
Energy Factors	**Electricity**	**Heat**	**Electricity**	**Heat**
*Area (kWh/m2*year)*	128.8	46.8	114.2	31.3
*Height (kWh/m*year)*	-3906.0	89365.5	-1049.1	42811.4
*T_{in} winter (kWh/°C*year)*	24419.6	108546.0	13908.1	47006.4
*T_{in} Summer (kWh/°C*year)*	10249.7	599.9	888.7	-1000.8
*Plug in MT (kWh/Cabinet*year)[12]*	16755.2	-8374.2	18964.6	-15593.4
*Plug in LT (kWh/Cabinet*year)[13]*	19731.3	-10144.4	21974.2	-18419.6
*Opening hours (kWh/h*year)*	302.3	-15.0	97.1	-54.0
*Group 1 (kWh/Cabinet*year)*	4149.6	4262.1	5906.2	6948.9
*Group 2 (kWh/Cabinet*year)*	4788.9	4798.6	6798.6	7861.2
*Group 3 (kWh/Cabinet*year)*	10107.5	8974.3	10758.4	13851.4
*Group 4 (kWh/Cabinet*year)*	3237.1	1281.8	2705.5	2207.8
*Group 5 (kWh/Cabinet*year)*	7978.9	3409.2	7225.5	5537.4
*Group 6 (kWh/Cabinet*year)*	12327.6	5236.6	10545.6	8300.4
*Volume flow(kWh/(m3/h)*year)*	17.9	-1.9	17.5	-1.7
Constant	-2397786.8	-3094335.6	-927831.1	-973498.4
Error (%)	0.18%	0.36%	0.64%	1.07%

Table 4-8. Energy factors resume for hypermarket and supermarket establishments using floating condensing in Stockholm.

Floating Condensing	Discount Store		Convenience Store	
Energy Factors	**Electricity**	**Heat**	**Electricity**	**Heat**
*Area (kWh/m2*year)*	107.4	-21.6	28.8	18.2
*Height (kWh/m*year)*	-1132.5	3547.2	-636.9	667.8
*T_{in} winter (kWh/°C*year)*	3731.7	13298.7	554.3	1752.2
*T_{in} Summer (kWh/°C*year)*	773.5	-701.9	390.7	63.2
*Plug in MT (kWh/Cabinet*year)[12]*	13445.9	-12757.8	11731.9	-6849.3
*Plug in LT (kWh/Cabinet*year)[13]*	9063.7	-8141.7	17612.7	-8395.1
*Opening hours (kWh/h*year)*	26.3	-16.5	2.0	0.3
*Group 1 (kWh/Cabinet*year)*	2448.3	5999.9	3198.8	3430.2
*Group 2 (kWh/Cabinet*year)*	2968.9	6761.2	4295.4	3802.9
*Group 3 (kWh/Cabinet*year)*	5380.7	11709.2	6650.6	7453.9
*Group 4 (kWh/Cabinet*year)*	2116.5	2040.8	2905.8	1229.2
*Group 5 (kWh/Cabinet*year)*	6138.5	5032.8	7203.7	3347.3
*Group 6 (kWh/Cabinet*year)*	9218.0	7536.9	10764.2	5251.5
*Volume flow(kWh/(m3/h)*year)*	24.0	-3.0	12.5	-1.8
Constant	-188473.7	-185882.3	-6340.6	-29371.2
Error (%)	0.65%	1.56%	1.08%	6.24%

[12] Cabinet considered MT: 2000 W
[13] Cabinet considered LT: 2000 W

Table 4-9. Relative energy factors for hypermarket and supermarket establishments using floating condensing in Stockholm.

Floating Condensing	Hypermarket		Supermarket	
Energy Factors	**Electricity**	**Heat**	**Electricity**	**Heat**
*Area (kWh/m2*year)*	0,003%	0,007%	0,008%	0,007%
*Height (kWh/m*year)*	-0,085%	13,200%	-0,072%	9,614%
*T_{in} winter (kWh/°C*year)*	0,531%	16,034%	0,956%	10,556%
*T_{in} Summer (kWh/°C*year)*	0,223%	0,089%	0,061%	-0,225%
*Plug in MT (kWh/Cabinet*year)*	0,364%	-1,237%	1,304%	-3,502%
*Plug in LT (kWh/Cabinet*year)*	0,429%	-1,498%	1,511%	-4,136%
*Opening hours (kWh/h*year)*	0,007%	-0,002%	0,007%	-0,012%
*Group 1 (kWh/Cabinet*year)*	0,090%	0,630%	0,406%	1,561%
*Group 2 (kWh/Cabinet*year)*	0,104%	0,709%	0,468%	1,765%
*Group 3 (kWh/Cabinet*year)*	0,220%	1,326%	0,740%	3,111%
*Group 4 (kWh/Cabinet*year)*	0,070%	0,189%	0,186%	0,496%
*Group 5 (kWh/Cabinet*year)*	0,173%	0,504%	0,497%	1,244%
*Group 6 (kWh/Cabinet*year)*	0,268%	0,774%	0,725%	1,864%
*Volume flow(kWh/(m3/h)*year)*	0,000%	0,000%	0,001%	0,000%

Table 4-10. Relative energy factors for discount and convenience establishments using floating condensing in Stockholm.

Floating Condensing	Discount Store		Convenience Store	
Energy Factors	**Electricity**	**Heat**	**Electricity**	**Heat**
*Area (kWh/m2*year)*	0,030%	-0,020%	0,041%	0,229%
*Height (kWh/m*year)*	-0,313%	3,335%	-0,902%	8,389%
*T_{in} winter (kWh/°C*year)*	1,031%	12,501%	0,785%	22,011%
*T_{in} Summer (kWh/°C*year)*	0,214%	-0,660%	0,553%	0,794%
*Plug in MT (kWh/Cabinet*year)*	3,715%	-11,993%	16,614%	-86,040%
*Plug in LT (kWh/Cabinet*year)*	2,504%	-7,654%	24,941%	-105,458%
*Opening hours (kWh/h*year)*	0,007%	-0,016%	0,003%	0,004%
*Group 1 (kWh/Cabinet*year)*	0,676%	5,640%	4,530%	43,090%
*Group 2 (kWh/Cabinet*year)*	0,820%	6,356%	6,083%	47,772%
*Group 3 (kWh/Cabinet*year)*	1,486%	11,007%	9,418%	93,635%
*Group 4 (kWh/Cabinet*year)*	0,585%	1,918%	4,115%	15,440%
*Group 5 (kWh/Cabinet*year)*	1,696%	4,731%	10,201%	42,048%
*Group 6 (kWh/Cabinet*year)*	2,547%	7,085%	15,243%	65,969%
*Volume flow(kWh/(m3/h)*year)*	0,007%	-0,003%	0,018%	-0,023%

4.2.3 Energy factors encompassing

In this section a deeper analysis concerning the energy factors is performed. The first think to highlight is the impossibility to understand the reason of all the signs and values. The global energy system of this establishments is quite complex, with many interconnections between different subsystems, what can result in some incomprehensible results. Moreover, to be able to understand all the signs a deeper look at CyberMart should be taken.

As an example, in all stores energy factors of the cabinets in the refrigeration system are positive, but for the heat factors in a discount store, where incomprehensibly the number of cabinets reduces the amount of heat needed to supply. If a closer look is taken to CyberMart, whenever the number of cabinets is increased, it results the total heat required by a discount store building also increases, however, the amount of heat recovered from the condensers rises even more, resulting in less heat to be delivered to the building. To comprehend the reason why this happens, a deeper analysis of CyberMart should be performed.

Conclusions extracted from these tables are presented down below. These conclusions are separated in two different groups, conclusions which seem logical and can be easily reasoned within the supermarket energy system and conclusions which have a more difficult understanding behind.

Unpredictable conclusions.

- The increase of height of the building drops the electricity demand.
- The increase of opening hours of the establishment increases the electricity use and reduces the heat demand. This occurs in all the buildings but the discount store, in which the heat demand is also reduced using both technologies.

Logical conclusions.

- The increase of area rises electricity and heat demands, except for the discount store, where the increase of area reduces the heat demand using both technologies.
- The rise of inside temperature during winter increases both the electricity and heat demand.
- The increase of plug in cabinets for both MT and LT increases the electricity demand and reduces the heat energy use.
- As the example above states, the more cabinets contained in the refrigeration system the more electricity and heat demands. This occurs in all studied cases but the discount store using heat recovery, where the heat is incomprehensibly reduced.
- The rise of volume flow increases the electricity use and reduces the heat demand.
- The relative energy factors from the cabinets (groups 1-6) are increased with the power of the cabinets.
- Concerning the number of cabinets of the refrigeration system, the lower the supermarket size, the higher the relative values. In other words, the increase of cabinets in smaller food stores has a higher impact than in big ones.
- Generally, in all the establishments but the discount store, the electricity factors are higher using heat recovery technology than floating condensing. This makes sense considering floating condensing technology aims to reduce the electricity energy use.
- For both hypermarkets and supermarkets, the relative factor with the higher average value for electricity and heat is the inside temperature in winter. However, for discount and convenience stores, cabinets gain prominence, especially plug in LT cabinets and the ones from groups 3 and 6.

- The lower the establishment size, the higher the errors become, with the errors associated to heat always higher than the electricity ones.

Therefore, energy factors enable supermarkets owners not only to simulate the global energy system within their establishment, but also to compare different parameters inside it and focus accordingly. Energy factors bring forward the effect of the parameter concerning the total energy system, providing valuable information when trying to get a sustainable establishment.

However, even though the highest error concerning electricity factors is only 1.08%, when treating with heat equations the error is highly increased, reaching a highest value of 6.24% in the convenience store. In this direction, supermarket owners should also consider the quadratic equations, especially when simulating the heat representation. Moreover, energy factors should be used to compare energy terms and to get an insight of the system, but when the total energy is the main purpose, they should always go together with the quadratic equations.

In conclusion, in this work two energy representations have been presented, both based in fourteen general parameters, which are selected to achieve a distributed representation of the establishment energy system. These two energy representations might work together in order to get the major benefits for the total system, getting a high accuracy from the quadratic representation and a deeply understating of the system from the energy factors, which also allow a comparison between different energy terms and the effect of each parameter in the global energy system.

4.3 Most energy-efficient supermarket results

Finally, the results regarding the most energy efficient establishments in Stockholm are presented. Annex 8-27 shows the potential COP's used for each sub-system depending on the outside temperature (Karampour, 2017). In order to calculate the optimum energy for the heating and cooling systems, which will be satisfied by heat pumps and chillers respectively, the hourly heat loads are divided by the COP's, obtaining the electricity consumption of the heat pump or the AC system. Similarly, for the refrigeration system the evaporator load is used to get the electricity use in the compressors. Regarding the DHW, the COP is considered constant, at a value of 5.4.

However, Annex 8-27 presents different ways to satisfy the required energy loads. ASHP, GSHP and CO_2 heat pumps are three different options to satisfy the heating demand of the establishments. In this direction, Figure 4-1 presents a comparison between the three stated systems, providing the total electricity use of the system for the first 156 hours of the year for a hypermarket in Stockholm. These hours are selected when the heating system is running (winter). It can be extracted that the CO_2 system is the most efficient one and therefore the one selected for the design of the most energy-efficient supermarket.

Similarly, Figure 4-2 contrasts two AC systems, working with R410 and CO_2, respectively. Similarly to above, the hours are selected when the AC system is running (summer). In this case, unlike the heating system, the AC working with a HFC refrigerant (R410A) presents a higher performance and consequently is the selected scheme. With regards to refrigeration systems, considering CO_2 systems are known to have a higher performance than HFC ones, no comparison is needed in that direction (Sawalha, 2017).

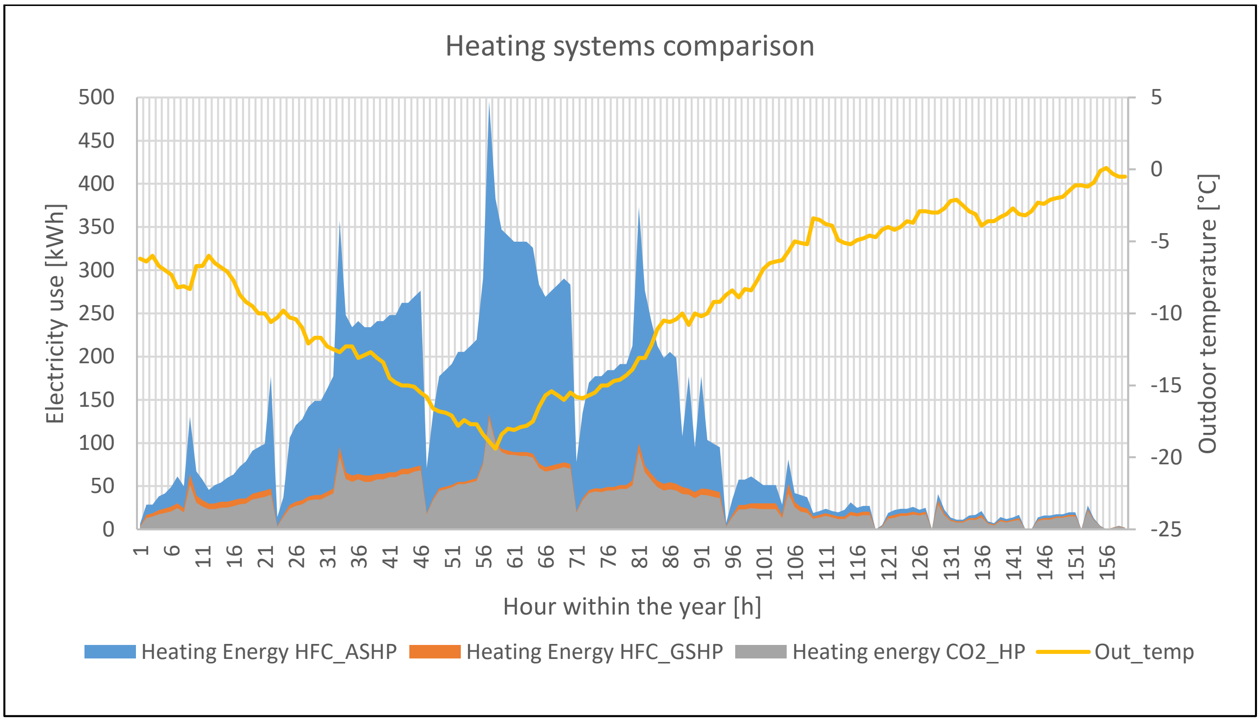

Figure 4-1. Electricity use comparison between three different heat pumps for a Hypermarket in Stockholm

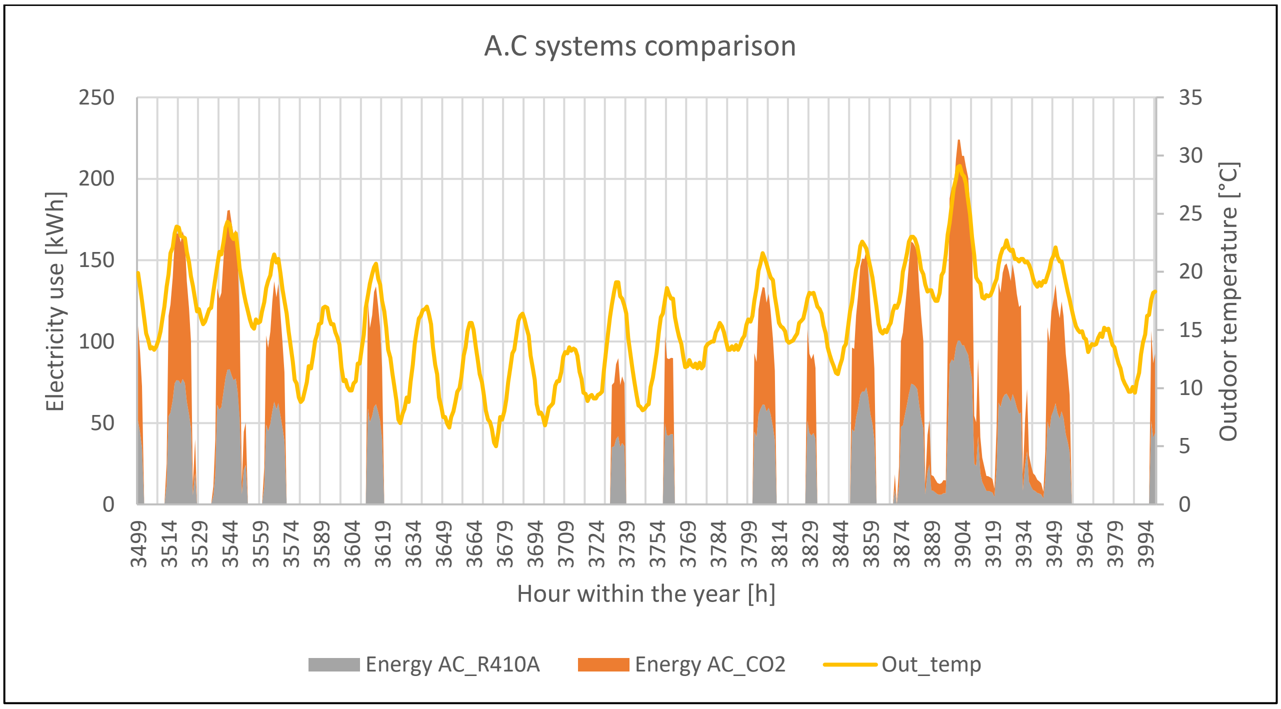

Figure 4-2. Electricity use comparison between two different AC systems for a Hypermarket in Stockholm

Once the electricity use of the most-energy systems is calculated, it is time for a comparison between the optimum results and the values from CyberMart. Nevertheless, considering some results from CyberMart are provided as heat, the concept of primary energy is brought forward, with the primary energy factors [14] for electricity and heat set to 2.5 and 1.0, respectively (Liu, 2014). Table 4-11 shows the obtained results, presented as primary energy use per square meter and the difference between both cases.

Table 4-11. Primary energy results for each establishment size

Establishment	Total area [m2]	Optimum Case [kWh/year*m^2]	CyberMart Case [kWh/year*m^2]	Difference [%]
Hypermarket	11600	956	1069	10.6
Supermarket	3500	984	1187	17.1
Disc. Store	924	975	1163	16.1
Conv. Store	232	702	795	11.7

As the table above presents, Supermarkets and Discount stores have a higher energy use per square meter than Hypermarkets, which can be explained considering the effect of the refrigeration system in the global establishment. In other words, the rate of refrigeration power per square meter of store is 30.9 W/m^2 for hypermarkets, whereas in supermarkets is 55.7 W/m^2 and in discount stores 61.7 W/m^2. Therefore, in supermarkets and discount stores the effect of the refrigeration system per square meter is much higher than in hypermarkets, fact that can explain the higher energy consumption in those establishments.

Calculations in Table 4-11 are based in a CyberMart case using a heat recovery technology. If a floating condensing technology is used, although the heat use would be highly increased, the total primary energy would similar due to the electricity reduction, considering the same energy factors of 2.5 and 1.0. As Convenience store don't use neither heat recovery nor floating condensing technologies, CyberMart results are the same in this case. Annex 8-28 presents this case.

All results presented until now, are based in the primary energy factors, which change depending on the country and the year. In this direction, Annex 8-29 and Annex 8-30 show a different scenario, using 1.6 and 1.0 as primary energy factors for electricity and heat respectively. Annex 8-29 contains the results using heat recovery technology while Annex 8-30 presents a floating condensing technology.

Furthermore, considering in the optimum case heat pumps and chillers using electricity satisfy heating and cooling purposes, all the power of the building ends to be electricity, what enables Table 4-12 to present all the energy demand of each establishment using this energy form.

Table 4-12. Electricity use for the Optimum case

Establishment	Optimum case electricity use [kWh/year*m^2]
Hypermarket	382
Supermarket	394
Disc. Store	390
Conv. Store	281

[14] Factor which converts an energy form to primary energy

Finally, Figure 4-3 represents Table 4-11 graphically, enabling a visual comparison between the studied cases and the different store sizes in Stockholm. On the other hand, Figure 4-4 represents a comparison between the optimum and CyberMart cases, which supermarkets owners should use as references to find out their real position in the food store scale.

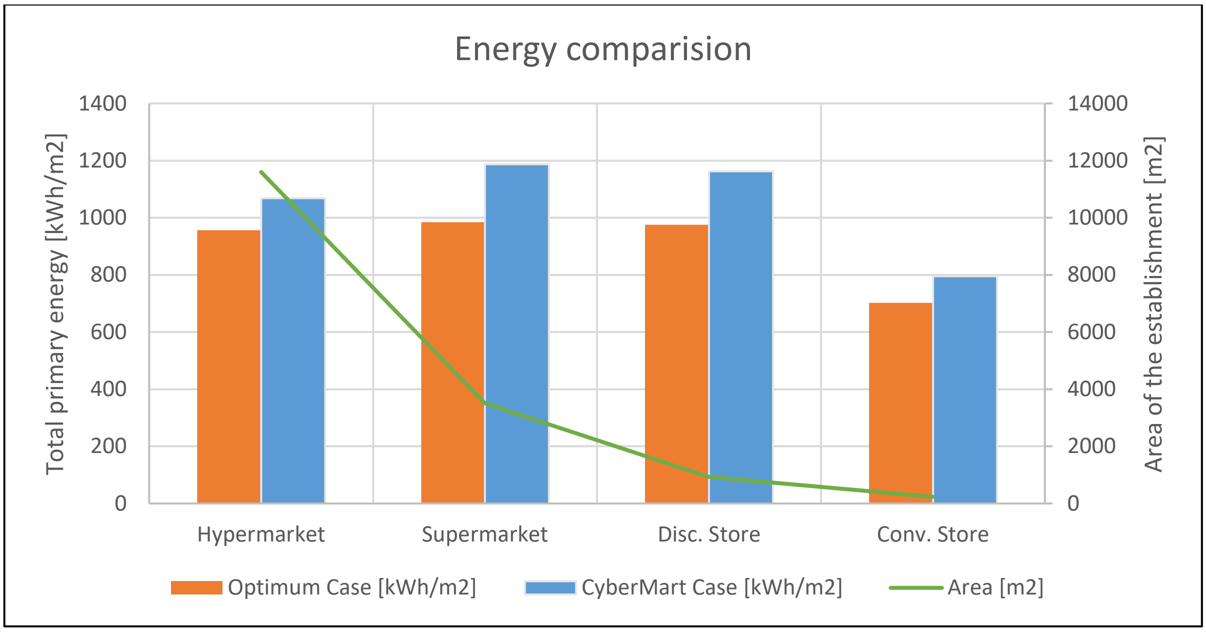

Figure 4-3. Energy comparison between the two cases for each establishment size

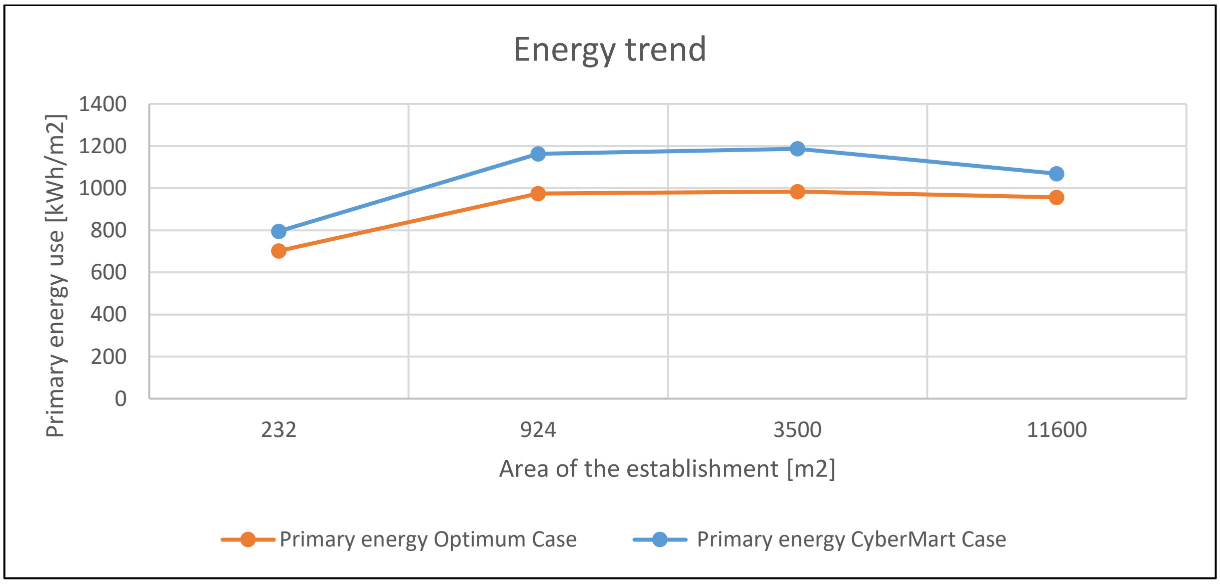

Figure 4-4. Energy trends for the optimum electricity case and the primary energies for both cases

5 Discussions

The analysis performed in this research, based on CyberMart and four reference stores cases, and encompassed by the EU project SuperSmart, tries to clear up the understanding of the global energy system in the food store world in order to reduce its impact to the environment. In the path to achieve its objective, this work presents an energy representation which enables the simulation of the complex energy system without the necessity of the software CyberMart, as well as the submission of the most energy-efficient establishment.

The energy representation presented in this research contains two distinguished parts, both based on fourteen different parameters within the supermarket energy system. These parameters, which are selected after many simulations with CyberMart, are the most influencing parameters in the global energy system and try to represent all sub-systems and aspects inside food stores. While the first part of the energy representation, which is composed by quadratic equations, aims to provide the electricity and heat demands of the establishment with a high accuracy, the second part enables a comparison between the fourteen selected parameters and uncovers the direct influence of each parameter with regards to electricity and heat demands. This second part is composed by linear equations and each of its parameter is known as energy factor.

Although the energy representation results can be used in different store sizes and two distinguished refrigeration technologies, their extension and quality could be increased in several ways. In this direction, equations differing months of the year, different European locations or including other input parameters like the R.H could be performed, always considering that the higher number of simulations provided to the software XLSTAT, the more accuracy achieved.

The conclusions extracted from the energy factors are occasionally surprising, due to the different interconnections between different sub-systems of the establishment. However, it can be extracted the factor with more influence in hypermarkets and supermarkets energy systems is the inside temperature in winter. In Discount and Convenience stores, cabinets gain prominence, especially plug in LT cabinets and the ones from groups 3 and 6.

Performing the obtained equations with real food stores, would provide a real test to the energy representation results and would supply valuable information in order to decide whether the options in the second paragraph should be implemented or not. This option, however, was intended to be carried out, but the lack of information delivered by different supermarkets chains precluded this part to be performed.

Another possible implementation in the energy representation would be referring the energy factors to their cost of investment. In other words, their unit could be kWh changed per euro invested in the parameter. In this way, supermarkets owners would be able to know where they should invest first. As an example, considering the inside temperature in winter and the number of cabinets, the costs of changing one degree the temperature of the store and the cost of purchasing a new cabinet should be included in the energy factor, enabling supermarkets owners to find out where they should invest.

The last results delivered in this research present the most energy efficient supermarket, or in other words the energy trend at which all supermarkets owners should point. This design, which is performed with the highest achievable COP's of refrigeration, heating and cooling systems, shows the lowest energy use that could be obtained by different store sizes in Stockholm.

SuperSmart project develops an ecolabel criteria based on a punctuation system with the function to determine whether an establishment is sustainable or not. Both the energy representation and the most efficient establishment design might help in the development of these criteria. In other words, the number of points provided to each food store could depend on how far they are from the most energy efficient store, with the two energy representations used as the instruments to determine this distance.

In conclusion, the tools provided in this research aim to take a step forward on the food stores sustainability path, supplying supermarkets owners with energy representations and trends containing valuable information. Using these tools, supermarkets owners can both increase their understanding of their own energy system and try to focus on their outstanding parameters to fulfil sustainable goals.

6 Conclusions

The number of interconnections and complexity of the supermarket energy system makes its study a difficult task to conduct. The connection between the refrigeration system, which is the most energy using system in a food store, and the HVAC, using the heat rejected by the condensers to reduce the heat demand of the building, is an important issue to understand the global energy system.

The type of refrigeration technology has a strong impact in the supermarket energy system. Considering the results obtained from CyberMart, the best option would be mixing heat recovery with floating condensing technologies.

Factors like the lights and the cover of the cabinets are highly determinant when studying the sustainability of food stores. In fact, in the results obtained in this work they are considered invariant, due to the assumption that both measures must be energy-efficient. In other words, it is considered unworthy to study the sustainability of stores where the cabinets are not closed and the lighting system is inefficient.

The temperature inside at winter highly effects the total energy use of the establishments, with an increase of this effect when the establishment area is raised. The refrigeration capacity has also a big impact in the global energy system. Furthermore, the less store area, the more influence of the refrigeration capacity in the global system.

However, when analyzing all energy factors, some unpredictable conclusions appear. Cases like the decline of electricity demand when the height of the building increases or the drop of heat demand with the rise of opening hours are unreasonable. To understand the reason of these cases, a deeper analysis concerning CyberMart is needed.

Finally, concerning the most energy-efficient establishment in Stockholm, CO_2 systems satisfy refrigeration and heating purposes, while AC systems use R410A. The obtained results showed an annual electricity use of 382, 394, 390 and 281 kWh/m^2 per each establishment size, with the highest energy use per square meter in Supermarkets and Discount stores, due to their higher rate of refrigeration power per store area.

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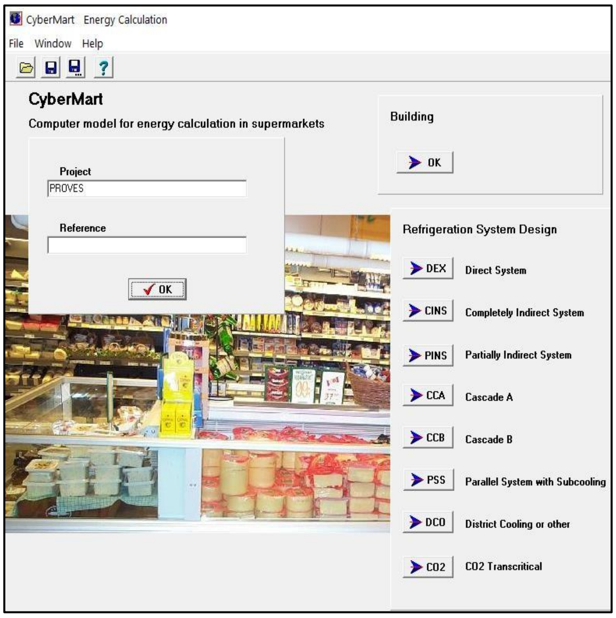
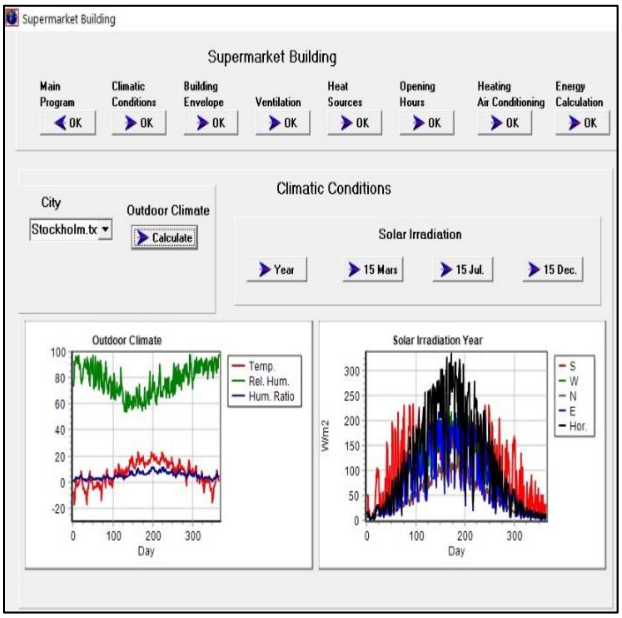
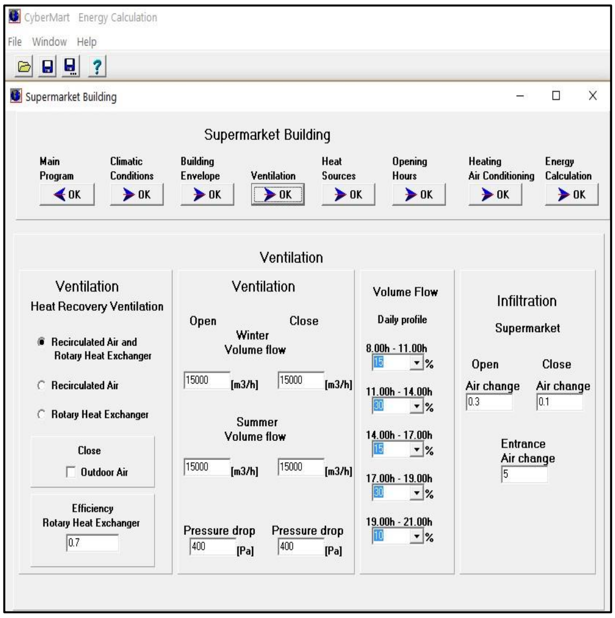
8 Annexes



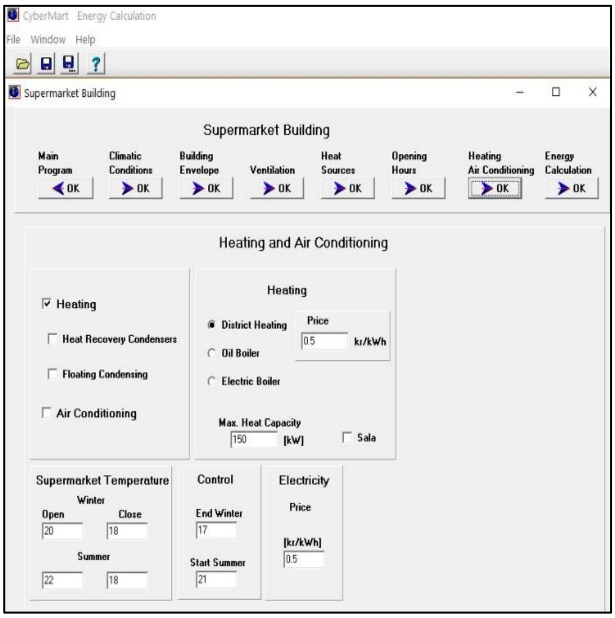
Annex 8-1. CyberMart Menu



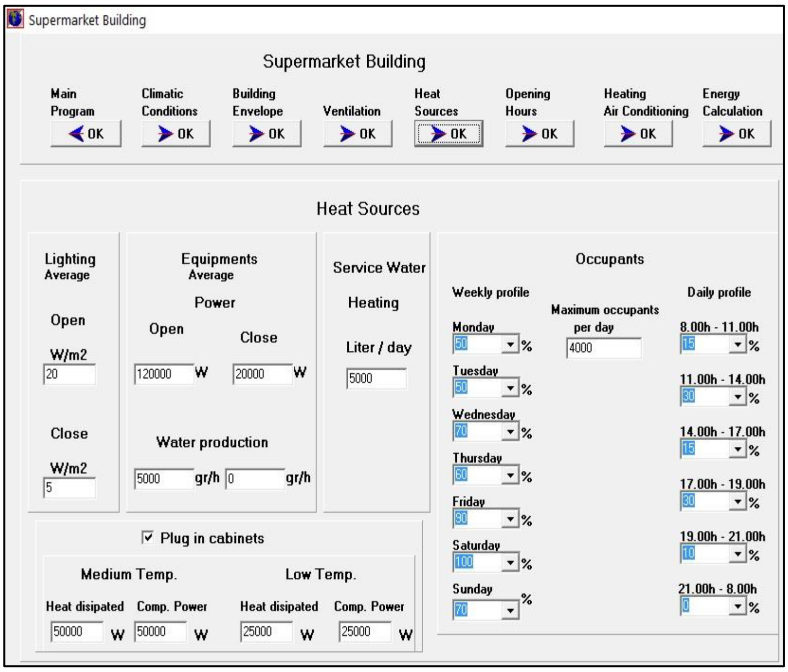
Annex 8-2. CyberMart climatic conditions Menu



Annex 8-3. CyberMart Ventilation Menu



Annex 8-4. CyberMart Heating and Air Conditioning Menu



Annex 8-5. CyberMart heat sources Menu

Month	El. Fan	El. Light	El. Equip	El. Plug	El. Comp	El. Ref	El. AC	El. Total	Heat	DHW
January	44640	124062	61380	45172,3	80238,97	115091,2	0	390345,5	52307,6	8370
February	40320	112056	55440	40454,7	71981,96	103449	0	351719,8	46593,1	7560
March	44640	124062	61380	45856,5	81266,15	116311	0	392249,5	31349,6	8370
April	43200	120060	59400	46861,2	82397,68	116775,7	247,12	386544	14225,8	8100
May	44640	124062	61380	53072,4	92501,24	128903,6	4289,83	416347,9	8596,93	8370
June	43200	120060	59400	57052,9	98587,64	134568,7	10457,2	424738,7	8100	8100
July	44640	124062	61380	61548,9	105853,2	143290,3	13520,7	448441,8	8370	8370
August	44640	124062	61380	61676,3	105891,1	143169	11096,4	446023,7	8370	8370
September	43200	120060	59400	55778,9	95888,51	131299	2917,51	412655,4	8147,12	8100
October	44640	124062	61380	52339,5	90758,38	126658,4	271,59	409351,5	9629,56	8370
November	43200	120060	59400	47091	82544,95	116636,9	0	386387,8	18944	8100
December	44640	124062	61380	46313,9	81874,61	116825	0	393220,9	40259	8370
TOTAL	525600	1460730	722700	613218	1069784	1492978	42800,3	4858026	254893	98550

Annex 8-6. Monthly results for the reference Hypermarket case provided by CyberMart.

Hypermarket reference case data

				HYPERM.
Building	Envelope	Dimension length (m)		116
		Dimension width (m)		100
		Height of the ceiling (m)		10
		Total area (m2)		11600
		Sales area (m2)		8000
		Percentage of sales area (%)		68,97
		Stand-alone		YES
		Building integrated		NO
		Partially building integrated		NO
		Wall 1	U	Light
			Window area	400
			Window type	Double gl, Kappa
			Window shield	Aluminum foil
		Wall 2	U	Light
			Window area	350
			Window type	Double gl, Kappa
			Window shield	Aluminum foil
		Wall 3	U	Light
			Window area	50
			Window type	Double gl, Kappa
			Window shield	Aluminum foil
		Wall 4	U	Light
			Window area	50
			Window type	Double gl, Kappa
			Window shield	Aluminum foil
		Roof	U	Light
		Floor	U	Light
		Edge insulation	Horizontal edge insulation	NO
			Vertical edge insulation	NO
	Ventilation	Recirculated air and RHE		NO
		Recirculated air		YES
		RHE		NO
		Outdoor air		YES
		Efficiency RE		NO
		Volume flow	Winter OPEN	90000
			Winter CLOSE	90000
			Summer OPEN	90000
			Summer CLOSE	90000
		Pressure drop	OPEN	300
			CLOSE	300
		Volume flow	8.00-11.00	100
			11.00-14.00	100
			14.00-17.00	100
			17.00-19.00	100
			19.00-21.00	100
		Infiltration air change (-)	OPEN	0,3
			CLOSE	0,1
		Entrance Air Change (-)		5
	Heat sources	Lighting (W/m2)	OPEN	20
			CLOSE	5
		Equipment (W)	OPEN	12000
			CLOSE	20000
		Water production (gr/h)	OPEN	5000
			CLOSE	0
		Service water heating (l/day)		5000
		Plug in cabinets MT	Heat diss (W)	50000
			Comp power (W)	50000
		Plug in cabinets LT	Heat diss (W)	25000
			Comp power (W)	25000
		Occupants weekly	Monday	50
			Tuesday	50
			Wednesday	70
			Thursday	60
			Friday	90
			Saturday	100
			Sunday	70
		Maximum occupants per day		4000
		Occupants daily	8.00-11.00	15
			11.00-14.00	30
			14.00-17.00	15
			17.00-19.00	30
			19.00-21.00	10
			21.00-8.00	0
	Opening hours	Monday-Friday	OPEN	8
			CLOSE	22
		Saturday	OPEN	8
			CLOSE	22
		Sunday	OPEN	8
			CLOSE	22
	Heating and AC	Heat recovery	Heat recovery condensers	YES
			Floating Condensing	NO
			Temperature cooler fluid after condenser	30
		Heating	District cooling	YES
			District heating price	0,6
			Oil boiler	NO
			Oil boiler price	NO

			Electric boiler	NO
			Maximum heat capacity (kW)	700
		Air Conditioning	Maximum cooling capacity (kW)	300
			Chiller Tin water °C	7
			Chiller Tout water °C	15
			District cooling	NO
			District cooling price	NO
		Supermarket temperature	Winter OPEN	20
			Winter CLOSE	20
			Summer OPEN	22
			Summer CLOSE	22
		Electricity price		1
		Control	End winter	14
			Start summer	17
REFRIGERATION	Type of refrigeration system			INDIRECT
	Medium Temperature		Refrigerant	R404A
			Compressor	RECIPROCATING BITZER
			Dry cooling fluid	Propylene glycol
			Brine	Ethylene glycol
			Number of rack	1
			Night cover cabinets	YES
			Number of cabinets model	10
			Cabinets with door	YES
			Cold storages	6
			Refrigeration capacity	289 kW
	Low Temperature		Refrigerant	R404A
			Compressor	RECIPROCATING BITZER
			Dry cooling fluid	Propylene glycol
			Brine	Pekasol 50 90%
			Number of rack	1
			Night cover cabinets	YES
			Number of Deep Freeze cabinets models	3
			Deep Freeze cabinets with door	YES
			Deep Freeze storages	2
			Refrigeration capacity	69 kW
	Defrost			Electric defrost

Annex 8-7. Hypermarket reference case data

Supermarket reference case data

				SUPERM.
Building	Envelope	Dimension length (m)		70
		Dimension width (m)		50
		Height of the ceiling (m)		4
		Total area (m2)		3500
		Sales area (m2)		2500
		Percentage of sales area (%)		71,42
		Stand-alone		YES
		Building integrated		YES
		Partially building integrated		YES
		Wall 1	U	Medium
			Window area	20
			Window type	Double gl, gl only
			Window shield	NO
		Wall 2	U	Medium
			Window area	20
			Window type	Double gl, gl only
			Window shield	NO
		Wall 3	U	Medium
			Window area	20
			Window type	Double gl, gl only
			Window shield	NO
		Wall 4	U	Medium
			Window area	12
			Window type	Double gl, gl only
			Window shield	NO
		Roof	U	Medium
		Floor	U	Medium
		Edge insulation	Horizontal edge insulation	NO
			Vertical edge insulation	NO
	Ventilation	Recirculated air and RHE		NO
		Recirculated air		YES
		RHE		NO
		Outdoor air		YES
		Efficiency RE		NO
		Volume flow	Winter OPEN	33000
			Winter CLOSE	33000
			Summer OPEN	33000
			Summer CLOSE	33000
		Pressure drop	OPEN	300
			CLOSE	300
		Volume flow	8.00-11.00	100
			11.00-14.00	100
			14.00-17.00	100
			17.00-19.00	100
			19.00-21.00	100
		Infiltration air change (-)	OPEN	0,4
			CLOSE	0,1
		Entrance Air Change (-)		5
	Heat sources	Lighting (W/m2)	OPEN	20
			CLOSE	2
		Equipment (W)	OPEN	25000
			CLOSE	1000
		Water productio	OPEN	1000
			CLOSE	500

		n (gr/h)		
		Service water heating (l/day)		1500
		Plug in cabinets MT	Heat diss (W)	8000
			Comp power (W)	8000
		Plug in cabinets LT	Heat diss (W)	5000
			Comp power (W)	5000
		Occupants weekly	Monday	50
			Tuesday	50
			Wednesday	70
			Thursday	60
			Friday	90
			Saturday	100
			Sunday	70
		Maximum occupants per day		2000
		Occupants daily	8.00-11.00	15
			11.00-14.00	30
			14.00-17.00	15
			17.00-19.00	30
			19.00-21.00	10
			21.00-8.00	0
	Opening hours	Monday-Friday	OPEN	8
			CLOSE	21
		Saturday	OPEN	8
			CLOSE	21
		Sunday	OPEN	10
			CLOSE	21
	Heating and AC	Heat recovery	Heat recovery condensers	YES
			Floating Condensing	NO
			Temperature cooler fluid after condenser	32
		Heating	District heating	YES
			District heating price	0,6
			Oil boiler	NO
			Oil boiler price	NO
			Electric boiler	NO
			Maximum heat capacity (kW)	150
		Air Conditioning	Maximum cooling capacity (kW)	30
			Chiller Tin water °C	5
			Chiller Tout water °C	10
			District cooling	NO
			District cooling price	NO
		Temperature	Winter OPEN	21
			Winter CLOSE	16
			Summer OPEN	21
			Summer CLOSE	21
		Electricity price		0,65
		Control	End winter	17
			Start summer	20
REFRIGERATION	Type of refrigeration system			INDIRECT
	Medium Temperature		Refrigerant	R404A
			Compressor	RECIPROCATING BITZER

		Dry cooling fluid	Propylene glycol
		Brine	Propylene glycol
		Number of rack	1
		Night cover cabinets	YES
		Number of cabinets model	3
		Cabinets with door	YES
		Cold storages	2
		Refrigeration capacity	169 kW
	Low Temperature	Refrigerant	R404A
		Compressor	RECIPROCATING BITZER
		Dry cooling fluid	Propylene glycol
		Brine	Carbon Dioxide
		Number of rack	1
		Night cover cabinets	YES
		Number of Deep Freeze cabinets models	3
		Deep Freeze cabinets with door	YES
		Deep Freeze storages	1
		Refrigeration capacity	26kW
	Defrost		Electric defrost

Annex 8-8. Supermarket reference case data

Discount store reference case data

				DISCOUNT
Building	Envelope	Dimension length (m)		44
		Dimension width (m)		25
		Height of the ceiling (m)		3,5
		Total area (m2)		924
		Sales area (m2)		600
		Percentage of sales area (%)		20,91
		Stand-alone		NO
		Building integrated		YES
		Partially building integrated		NO
		Wall 1	U	Medium
			Window area	0
			Window type	NO
			Window shield	NO
		Wall 2	U	Medium
			Window area	0
			Window type	NO
			Window shield	NO
		Wall 3	U	Medium
			Window area	0
			Window type	NO
			Window shield	NO
		Wall 4	U	Medium
			Window area	15
			Window type	Double glass
			Window shield	Aluminum foil
		Roof	U	Medium
		Floor	U	Medium
		Edge insulation	Horizontal edge insulation	NO
			Vertical edge insulation	NO
	Ventilation	Recirculated air and RHE		NO
		Recirculated air		YES
		RHE		NO
		Outdoor air		YES
		Efficiency RE		0,7
		Volume flow	Winter OPEN	6000
			Winter CLOSE	6000
			Summer OPEN	6000
			Summer CLOSE	6000
		Pressure drop	OPEN	400
			CLOSE	400
		Volume flow	8.00-11.00	100
			11.00-14.00	100
			14.00-17.00	100
			17.00-19.00	100
			19.00-21.00	100
		Infiltration air change (-)	OPEN	0,2
			CLOSE	0,1
		Entrance Air Change (-)		5
	Heat sources	Lighting (W/m2)	OPEN	20
			CLOSE	2
		Equipment (W)	OPEN	8000
			CLOSE	700
		Water production (gr/h)	OPEN	500
			CLOSE	250
		Service water heating (l/day)		1000
		Plug in cabinets MT	Heat diss (W)	0
			Comp power (W)	0
		Plug in cabinets LT	Heat diss (W)	3000
			Comp power (W)	3000
		Occupants weekly	Monday	50
			Tuesday	50
			Wednesday	70
			Thursday	60
			Friday	90
			Saturday	100
			Sunday	70
		Maximum occupants per day		1200
		Occupants daily	8.00-11.00	15
			11.00-14.00	30
			14.00-17.00	15
			17.00-19.00	30
			19.00-21.00	10
			21.00-8.00	0
	Opening hours	Monday-Friday	OPEN	9
			CLOSE	21
		Saturday	OPEN	9
			CLOSE	21
		Sunday	OPEN	9
			CLOSE	21
		Total hours year		4368
	Heating and AC	Heat recovery	Heat recovery condensers	YES
			Floating Condensing	NO
			Temperature cooler fluid after condenser	NO
		Heating	District heating	YES
			District heating price	0,6

			Oil boiler	NO
			Oil boiler price	NO
			Electric boiler	NO
			Maximum heat capacity (kW)	150
		Air Conditioning	Maximum cooling capacity (kW)	60
			Chiller Tin water °C	10
			Chiller Tout water °C	14
			District cooling	NO
			District cooling price	NO
		Supermarket temperature	Winter OPEN	20
			Winter CLOSE	20
			Summer OPEN	22
			Summer CLOSE	22
		Electricity price		0,65
		Control	End winter	17
			Start summer	20
REFRIGERATION	Type of refrigeration system			DIRECT SYSTEM
			Refrigerant	R404A

	Medium Temperature	Compressor	RECIPROCATING BITZER
		Dry cooling fluid	NO
		Brine	NO
		Number of rack	1
		Cabinets with door	YES
		Cold storages	4
		Refrigeration Capacity	48 kW
	Low Temperature	Refrigerant	R404A
		Compressor	RECIPROCATING BITZER
		Dry cooling fluid	NO
		Brine	NO
		Number of rack	1
		Deep Freeze cabinets with door	YES
		Deep Freeze storages	1
		Refrigeration Capacity	9 kW
	Defrost		Electric defrost

Annex 8-9. Discount store reference case data

Convenience store reference case data

				CONV.
Building	Envelope	Dimension length (m)		29
		Dimension width (m)		8
		Height of the ceiling (m)		3
		Total area (m2)		232
		Sales area (m2)		230
		Percentage of sales area (%)		99,14
		Stand-alone		NO
		Building integrated		YES
		Partially building integrated		NO
		Wall 1	U	Medium
			Window area	7
			Window type	Double gl, Kappa
			Window shield	NO
		Wall 2	U	Medium
			Window area	0
			Window type	NO
			Window shield	NO
		Wall 3	U	Medium
			Window area	0
			Window type	NO
			Window shield	NO
		Wall 4	U	Medium
			Window area	0
			Window type	NO
			Window shield	NO
		Roof	U	Medium
		Floor	U	Medium
		Edge insulation	Horizontal edge insulation	NO
			Vertical edge insulation	NO
	Ventilation	Recirculated air and RHE		NO
		Recirculated air		YES
		RHE		NO
		Outdoor air		YES
		Efficiency RE		0,7
		Volume flow	Winter OPEN	1000
			Winter CLOSE	1000
			Summer OPEN	1000
			Summer CLOSE	1000
		Pressure drop	OPEN	200
			CLOSE	200
		Volume flow	8.00-11.00	100
			11.00-14.00	100
			14.00-17.00	100
			17.00-19.00	100
			19.00-21.00	100
		Infiltration air change	OPEN	0,3
			CLOSE	0,05
		Entrance Air Change (-)		5
	Heat sources	Lighting (W/m2)	OPEN	13
			CLOSE	0
		Equipment (W)	OPEN	1000
			CLOSE	400
		Water production (gr/h)	OPEN	100
			CLOSE	50
		Service water heating (l/day)		50
		Plug in cabinets MT	Heat diss (W)	460
			Comp power (W)	460
		Plug in cabinets LT	Heat diss (W)	2000
			Comp power (W)	2000
		Occupants weekly	Monday	50
			Tuesday	50
			Wednesday	70
			Thursday	60
			Friday	90
			Saturday	100
			Sunday	70
		Maximum occupants per day		22
		Occupants daily	8.00-11.00	15
			11.00-14.00	30
			14.00-17.00	15
			17.00-19.00	30
			19.00-21.00	10
			21.00-8.00	0
	Opening hours	Monday-Friday	OPEN	9
			CLOSE	19
		Saturday	OPEN	10
			CLOSE	16
		Sunday	OPEN	10
			CLOSE	16
		Total hours year		3224
	Heating and AC	Heat recovery	Heat recovery condensers	NO
			Floating Condensing	NO
			Temperature cooler fluid after condenser	NO

		Heating	District heating	YES
			District heating price	0,5
			Oil boiler	NO
			Oil boiler price	NO
			Electric boiler	NO
			Maximum heat capacity (kW)	15
		Air Conditioning	Maximum cooling capacity (kW)	11
			Chiller Tin water °C	10
			Chiller Tout water °C	14
			District cooling	NO
			District cooling price	NO
		Supermarket temperature	Winter OPEN	16
			Winter CLOSE	16
			Summer OPEN	22
			Summer CLOSE	22
		Electricity price		1
		Control	End winter	12
			Start summer	15
REFRIGERATION	Type of refrigeration system			DIRECT SYSTEM
	Medium Temperature		Refrigerant	R404A
			Compressor	RECIPROCATING COPELAND
			Dry cooling fluid	NO
			Brine	NO
			Number of rack	1
			Number of cabinets model	1
			Cabinets with door	YES
			Cold storages	1
			Refrigeration Capacity	8 kW
	Low Temperature		Refrigerant	R404A
			Compressor	RECIPROCATING COPELAND
			Dry cooling fluid	NO
			Brine	NO
			Number of rack	1
			Number of Deep Freeze cabinets models	1
			Deep Freeze cabinets with door	YES
			Deep Freeze storages	0
			Refrigeration capacity	1 kW
	Defrost			Electric defrost

Annex 8-10. Convenience store reference case data

Parameter changed from the reference	New value of the parameter	Relative change from the reference [%]
Lights	30 W/m2	14.89
Lights	10 W/m2	14.18
Lights	25 W/m2	7.40
Lights	15 W/m2	7.15
Refrigeration Capacity MT	521	5.87
Refrigeration Capacity MT	485	4.70
Refrigeration technology	Floating condensing	4.36
Refrigeration Capacity LT	102	4.35
Refrigeration Capacity MT	470	4.35
Plug In (LT)	45000 W	3.90
Plug In (MT)	70000 W	3.64
Plug In (MT)	30000 W	3.51
Refrigeration Capacity MT	287	3.37
Refrigeration Capacity MT	289	3.31
Refrigeration Capacity LT	93	3.20
Refrigeration Capacity LT	44	3.07
Covers	No night covers (MT)	2.92
Plug In (LT)	10000 W	2.87
Refrigeration Capacity MT	319	2.72
Refrigeration Capacity MT	334	2.45
Refrigeration Capacity MT	427	2.05
Plug In (LT)	35000 W	1.94
Plug In (LT)	15000 W	1.92
Plug In (MT)	60000 W	1.80
Plug In (MT)	40000 W	1.77
Refrigeration Capacity LT	82	1.48
Height	5 m	1.38
Refrigeration Capacity MT	356	1.35
Integration	4 walls + roof + floor integrated	0.99
Refrigeration Capacity LT	61	0.97
Refrigeration Capacity MT	399	0.71

Windows	Venetian blind inside	0.48
Ventilation	Rotatory heat exchanger	0.26
Winter temperature	Winter 21°C	0.23
Occupants	6000 people	0.21
Occupants	2000 people	0.21
Summer temperature	Summer 23°C	0.16
Summer temperature	Summer 21°C	0.15
Height	7.5 m	0.14
Winter temperature	Winter 19°C	0.13
Ventilation	Recirculated air + rotatory heat exchanger	0.13
Walls	Heavy wall	0.13
Windows	Triple glass reflectasol	0.13
Walls	Medium wall	0.11
Integration	3 walls integrated	0.11
Occupants	5000 people	0.10
Occupants	3000 people	0.10
Windows	Triple g kappa sol	0.09
Windows	Sunshade auto	0.08
Entrance air	Entrance air change 4	0.06
Windows area	680 m2	0.05
Air change	Open air change 0.2	0.05
Windows area	1020 m2	0.05
Entrance air	Entrance air change 6	0.04
Windows area	765 m2	0.02
Windows area	935 m2	0.02
Air change	Open air change 0.4	0.02
Height	12.5 m	0.01
Height	15 m	0.01
Walls	Edge insulation	0.00
Reference	Reference	0.00

Annex 8-11. Results obtained with CyberMart with the Hypermarket reference data using a direct system in Spain (Barcelona).

Parameter changed from the reference	New value of the parameter	Relative change from the reference [%]
Refrigeration technology	Floating condensing	15.71
Refrigeration Capacity MT	95	14.17
Refrigeration Capacity MT	89	11.37
Refrigeration Capacity LT	22	9.35
Lights	30 W/m2	8.46
Refrigeration Capacity MT	58	8.34
Refrigeration Capacity MT	85	7.95
Refrigeration Capacity MT	63	6.55
Refrigeration Capacity LT	11	6.48
Lights	10 W/m2	5.45
Plug In (MT)	5000 W	5.20
Lights	25 W/m2	4.07
Covers	No night covers (MT)	3.72
Winter temperature	Winter 21°C	3.19
Lights	15 W/m2	3.09
Plug In (LT)	5000 W	2.46
Plug In (LT)	1000 W	2.11
Ventilation	Rotatory heat exchanger	1.23
Plug In (LT)	4000 W	1.20
Winter temperature	Winter 19°C	1.20
Plug In (LT)	2000 W	1.11
Occupants	2200 people	1.01
Plug In (MT)	1000 W	0.96
Integration	No walls integrated	0.82
Occupants	200 people	0.79
Height	5.5 m	0.78
Ventilation	Recirculated air + rotatory heat exchanger	0.66
Occupants	700 people	0.63
Air change	Open air change 0.3	0.61
Occupants	1700 people	0.58
Height	1.5 m	0.38

Walls	Heavy walls	0.36
Height	4.5 m	0.34
Air change	Open air change 0.1	0.24
Height	2.5 m	0.21
Walls	Light walls	0.17
Windows	Triple g kappa sol	0.05
Windows	Triple g reflectasol	0.05
Entrance air	Entrance air change 4	0.03
Walls	Edge insulations	0.03
Summer temperature	Summer 23°C	0.03
Summer temperature	Summer 21°C	0.03
Windows area	18 m2	0.03
Windows area	12 m2	0.03
Entrance air	Entrance air change 6	0.02
Windows area	16.5 m2	0.01
Windows area	13.5 m2	0.01
Integration	4 walls + roof + floor integrated	0.01
Windows	Venetian blind inside	0.00
Windows	Sunshade auto	0.00
Reference	Reference	0.00

Annex 8-12. Results obtained with CyberMart with the Disc Store reference data using a direct system in Stockholm.

Parameter changed from the reference	New value of the parameter	Relative change from the reference [%]
Plug In (MT)	3000 W	23,39
Plug In (LT)	4000 W	16.95
Refrigeration Capacity LT	2	15.01
Refrigeration technology	Floating condensing	10.66
Integration	4 walls + roof + floor integrated	10.31
Ventilation	Rotatory heat exchanger	8.41
Plug In (LT)	3000 W	7.39
Refrigeration Capacity MT	6	7.06
Refrigeration Capacity MT	3	7.03
Refrigeration technology	Heat recovery condenser	6.60
Lights	19 W/m2	5.61
Plug In (LT)	1000 W	5.60
Lights	7 W/m2	4.85
Walls	Heavy walls	3.87
Plug In (MT)	1000 W	3.41
Covers	No night covers (MT)	3.11
Lights	16 W/m2	2.73
Ventilation	Recirculated air + rotatory heat exchanger	2.69
Walls	Medium walls	2.57
Lights	10 W/m2	2.52
Integration	2 walls integrated	2.50
Winter temperature	Winter 18°C	2.44
Winter temperature	Winter 14°C	1.41
Height	4 m	1.30
Height	2 m	1.29
Air change	Open air change 0.4	0.99
Air change	Open air change 0.2	0.97
Windows	Triple g kappa sol	0.76
Windows	Triple g reflectasol	0.72
Walls	Edge insulations	0.68
Height	3.5 m	0.65
Height	2.5 m	0.65
Windows area	9 m2	0.58
Windows area	5 m2	0.57
Windows area	8 m2	0.29
Windows area	6 m2	0.29

Windows	Venetian blind inside	0.26
Entrance air	Entrance air change 6	0.17
Entrance air	Entrance air change 4	0.14
Summer temperature	Summer 23°C	0.13
Windows	Sunshade auto	0.11
Summer temperature	Summer 21°C	0.11
Occupants	12 people	0.06
Occupants	32 people	0.05
Occupants	17 people	0.03
Occupants	27 people	0.03

Annex 8-13. Results obtained with CyberMart with the Convenience store reference data using a direct system in Stockholm

Heat Recovery	Hypermarket electricity		Hypermarket heating		Supermarket electricity		Supermarket Heating	
X_i	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i
Area	-6.00E-05	133.64	4.14E-04	14.65	-3.69E-03	141.77	-9.22E-04	13.76
Height	636.64	-18778.47	3922.47	-31210.73	-334.74	4178.27	1682.40	15194.51
T_{in} winter	1931.24	-47310.68	27858.16	-1001888.13	304.10	6031.09	13116.91	-462975.81
T_{in} Summer	543.86	-18993.38	-47.28	2051.96	-371.76	15866.29	-78.34	2571.90
Plug in MT	9.33E-06	7.91	8.12E-06	-2.61	-6.50E-05	9.03	2.36E-05	-5.26
Plug in LT	8.15E-06	9.91	1.17E-05	-2.83	-6.76E-05	10.17	4.28E-05	-6.15
Opening hours	-1.47E-03	321.37	4.50E-03	-62.82	-2.34E-03	118.33	-2.39E-04	-39.96
$Group_1$	-43.98	8199.05	5.17	1395.79	286.67	-2218.59	27.11	3808.17
$Group_2$	-48.81	9458.87	6.44	1560.63	289.83	-1320.42	34.63	4174.97
$Group_3$	88.07	5070.67	34.08	1489.14	313.79	2682.66	122.09	5345.12
$Group_4$	27.47	2664.55	1.46	492.94	-386.72	7688.40	-28.20	1851.92
$Group_5$	66.31	6078.82	6.48	1184.06	-669.20	16528.71	-7.94	3889.26
$Group_6$	97.26	9457.92	13.26	1706.31	-557.12	19046.16	14.35	5508.50
Volume flow	1.95E-04	-17.01	2.46E-05	-7.64	5.16E-04	-15.68	5.89E-05	-9.74
Constant	395090.48		9438365.86		-402008.56		4139102.69	
Error	0.07%		0.13%		0.14%		0.36%	

Annex 8-14. Quadratic equations resume for hypermarket and supermarket establishments using heat recovery in Stockholm.

Heat Recovery	Discount Store electricity		Discount Store heating		Convenience Store electricity		Convenience Store heating	
X_i	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i
Area	-1.86E-02	143.30	4.74E-03	-9.33	-2.03E-01	142.43	-5.57E-03	33.14
Height	571.44	-4951.49	-57.66	572.63	1005.30	-7544.01	12.61	824.86
T_{in} winter	33.87	3890.32	247.71	-9210.44	93.56	-2753.18	67.37	-560.33
T_{in} Summer	-84.05	3797.54	11.62	-506.02	-82.25	3740.02	0.12	-9.76
Plug in MT	1.83E-04	6.90	-1.60E-05	4.16E-02	-5.02E-03	12.03	2.60E-04	-3.32
Plug in LT	-2.08E-05	9.12	1.77E-05	-0.18	4.22E-05	8.82	5.73E-04	-6.49
Opening hours	4.33E-03	-16.17	-6.78E-04	5.26	4.69E-03	-24.67	1.11E-04	-0.49
$Group_1$	87.47	3013.79	23.92	-239.42	-148.46	4097.62	191.07	1772.11
$Group_2$	86.62	3707.02	26.85	-279.49	-170.53	5056.72	281.28	1833.79
$Group_3$	158.97	6393.43	66.04	-509.36	114.63	6251.89	438.14	4598.47
$Group_4$	345.54	944.07	1.93	-20.24	-80.34	3366.70	-2.16	1242.79
$Group_5$	47.48	8412.95	36.56	-227.53	71.03	6926.34	104.40	2890.81
$Group_6$	13.07	12633.23	164.12	-869.21	-91.50	11273.60	130.30	4669.60
Volume flow	3.66E-03	-19.92	1.12E-03	-14.71	9.73E-03	-6.83	4.29E-05	-1.91
Constant	10928.22		155338.50		28820.41		-4975.20	
Error	0.14%		1.10%		0.78%		1.60%	

Annex 8-15. Quadratic equations resume for discount and convenience establishments using heat recovery in Stockholm.

Floating Condensing	Hypermarket electricity		Hypermarket heating		Supermarket electricity		Supermarket Heating	
X_i	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i
Area	3.01E-05	128.06	-1.98E-06	46.82	-8.45E-04	120.10	6.93E-03	-17.22
Height	581.90	-15544.08	1118.79	66989.67	-79.58	1817.62	547.12	37345.93
T_{in} winter	1641.62	-41245.31	5283.62	-102798.74	-3261.94	138618.49	-12366.44	525849.40
T_{in} Summer	1214.18	-41619.25	-30.86	1090.34	22.51	-56.50	903.70	-38956.07
Plug in MT	8.98E-06	7.48	8.35E-06	-5.02	1.21E-05	7.55	1.89E-04	-10.38
Plug in LT	8.01E-06	9.40	1.23E-05	-5.81	9.00E-06	9.15	1.91E-04	-10.68
Opening hours	-7.17E-04	305.76	6.62E-03	-76.69	-2.25E-04	98.57	5.92E-03	-107.50
$Group_1$	-57.88	8692.11	7.51	3725.53	243.77	-2381.99	53.85	5118.11
$Group_2$	-51.82	8863.22	14.03	3758.21	246.60	-1585.88	54.62	6004.15
$Group_3$	45.56	6707.19	31.72	6595.57	286.04	1033.02	62.94	11711.40
$Group_4$	24.26	2225.84	0.53	1351.96	-123.29	4184.92	440.46	-3077.71
$Group_5$	58.55	5321.76	4.97	3266.24	-330.50	11191.52	443.38	216.83
$Group_6$	89.67	8176.82	11.69	4770.80	-250.96	13557.21	447.62	2929.00
Volume flow	1.96E-04	-17.36	1.38E-06	-2.13	5.30E-04	-16.72	-7.47E-05	3.13
Constant	462187.44		-606551.57		-1351847.44		-4927880.51	
Error	0.07%		0.03%		0.13%		0.94%	

Annex 8-16. Quadratic equations resume for hypermarket and supermarket establishments using floating condensing in Stockholm.

Floating Condensing	Discount Store electricity		Discount Store heating		Convenience Store electricity		Convenience Store heating	
X_i	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i
Area	-0.11	310.94	0.10	-207.68	2.77E-01	-99.54	3.05E-01	-123.16
Height	3499.93	-31352.72	-2365.41	24591.14	932.87	-6995.31	-20.26	1071.43
T_{in} winter	-428.66	20219.69	785.20	-16766.72	87.09	-2501.07	64.65	-458.65
T_{in} Summer	-532.25	23292.47	391.99	-17524.13	-80.88	3738.83	3.27	-146.13
Plug in MT	8.58E-04	4.17	-4.52E-04	-4.61	-4.62E-03	11.45	4.69E-04	-3.54
Plug in LT	-1.80E-03	19.78	1.58E-03	-17.40	-9.00E-06	8.84	5.83E-04	-6.53
Opening hours	-2.91E-03	51.73	2.05E-03	-34.43	4.68E-03	-24.66	1.40E-04	-0.66
$Group_1$	-107.99	3452.64	281.65	3622.02	-179.27	4460.74	191.58	1768.17
$Group_2$	-109.74	3986.24	298.79	4256.52	-211.12	5474.97	283.74	1818.69
$Group_3$	-140.07	6622.36	430.14	8232.54	47.93	6811.48	438.65	4594.54
$Group_4$	145.64	770.97	105.75	1706.29	-81.97	3411.89	-2.67	1250.15
$Group_5$	23.07	5674.66	121.46	4585.30	57.88	7036.09	102.60	2905.00
$Group_6$	-4.79	8954.60	136.26	6982.93	-106.30	11392.25	128.46	4683.96
Volume flow	2.59E-03	-7.13	7.46E-04	-11.96	9.90E-03	-7.26	1.20E-04	-2.06
Constant	-610339.13		430906.68		54689.86		15135.10	
Error	0.58%		1.85%		0.80%		1.80%	

Annex 8-17. Quadratic equations resume for discount and convenience establishments using floating technology in Stockholm.

QUADRATIC EQUATIONS HEAT RECOVERY

Equation 8-1. Total energy representation hypermarket in Stockholm

Hypermarket. *Total energy (kWh) = 9571719.6 + 151.7*Area + (-46019.3)*Height + (-1041259.1)*T_{in} winter + (-11308.8)*T_{in} Summer + 8.2*Plug in MT + 7.2*Plug in LT + 257.6*Opening hours + 9804.5*Group$_1$ + 11229.1*Group$_2$ + 6694.8*Group$_3$ + 3230.2*Group$_4$ + 7335.6*Group$_5$ + 11236.9*Group$_6$ + (-24.3)*Volume flow + 2.1E-04*Area^2 + 4360.6*Height^2 + 29590.9*T in winter^2+ 366.8*T in Summer^2+ (-2.E-05)*Plug in MT^2 + 1.8E-05*Plug in LT^2 + 3.3E-03*Opening hours^2+ (-41.7)*Group$_1^2$+ (-45.2)*Group$_2^2$ + 120.1*Group$_3^2$ + 26.9*Group$_4^2$+ 70.7*Group$_5^2$ + 108.4*Group$_6^2$ + 2.2E-04*Volume flow^2*

Hypermarket. *Total electricity (kWh) = 395090.48+ 133.64*Area + (-18778.47)*Height + (-47310.68)*T_{in} winter + (-18993.38)*T_{in} Summer + 7.91*Plug in MT + 9.91*Plug in LT + 321.37*Opening hours + 8199.05*Group$_1$ + 9458.87*Group$_2$ + 5070.67*Group$_3$ + 2664.55*Group$_4$ + 6078.82*Group$_5$ + 9457.92*Group$_6$ + (-17.01)*Volume flow + (-6.00E-05)*Area^2 + 636.64*Height^2 + 1931.24*T in winter^2+ 543.86*T in Summer^2+ (9.33E-06)*Plug in MT^2 + 8.15E-06*Plug in LT^2 + -1.47E-03*Opening hours^2+ (-43.98)*Group$_1^2$+ (-48.81)*Group$_2^2$ + 88.07*Group$_3^2$ + 27.47Group$_4^2$+ 66.31*Group$_5^2$ + 97.26*Group$_6^2$ + 1.95E-04*Volume flow^2*

Hypermarket. *Total heat (kWh) = 9438365.86 + 14.65*Area + (-31210.73)*Height + (-1001888.13)*T_{in} winter + 2051.96*T_{in} Summer + (-2.61)*Plug in MT + (-2.83)*Plug in LT + (-62.82)*Opening hours + 1395.79*Group$_1$ + 1560.63*Group$_2$ + 1489.14*Group$_3$ + 492.94*Group$_4$ + 1184.06*Group$_5$ + 1706.31*Group$_6$ + (-7.64)*Volume flow + 4.14E-04*Area^2 + 3922.47*Height^2 + 27858.16*T in winter^2+ (-47.28)*T in Summer^2+ 8.12E-06*Plug in MT^2 + 1.17E-05*Plug in LT^2 + 4.50E-03*Opening hours^2+ 5.17*Group$_1^2$+ 6.44*Group$_2^2$ + 34.08*Group$_3^2$ + 1.46*Group$_4^2$+ 6.48*Group$_5^2$ + 13.26*Group$_6^2$ + 2.46E-05*Volume flow^2*

Equation 8-2. Total energy representation supermarket in Stockholm

Supermarket. *Total energy (kWh) = 3721594.5 + 141*Area + 17713.7*Height + (-461648.4)*T_{in} winter + 6046.5*T_{in} Summer + 2.7*Plug in MT + 3.3*Plug in LT + 209.8*Opening hours + 1048.2*Group$_1$ + 2313.2*Group$_2$ + 7486.4*Group$_3$ + 7820.7*Group$_4$ + 18698.3*Group$_5$ + 22835*Group$_6$ + (-25.9)*Volume flow + (-2.5E-03)*Area^2 + 1540.6*Height^2 + 13535.5*T in winter^2+ (-155)*T in Summer^2+ 1.7E-05*Plug in MT^2 + 3.3E-05*Plug in LT^2 + (-1.9E-02)*Opening hours^2+ 329.7*Group$_1^2$+ 340.4*Group$_2^2$ + 451.8 *Group$_3^2$ + (-271.6)*Group$_4^2$ + (-533.8)*Group$_5^2$ + (-399.5)*Group$_6^2$ + 5.8E-04*Volume flow^2*

Supermarket. *Total electricity (kWh) = -402008.56 + 141.77*Area + 4178.27*Height + 6031.09*T_{in} winter + 15866.29*T_{in} Summer + 9.03*Plug in MT + 10.17*Plug in LT + 118.33*Opening hours + (-2218.59)*Group$_1$ + (-1320.42)*Group$_2$ + 2682.66*Group$_3$ + 7688.40*Group$_4$ + 16528.71*Group$_5$ + 19046.16*Group$_6$ + (-15.68)*Volume flow + (-3.69E-03)*Area^2 + (-334.74)*Height^2 + 304.10*T in winter^2+ (-371.76)*T in Summer^2+ (-6.50E-05)*Plug in MT^2 + (-6.76E-05)*Plug in LT^2 + (-2.34E-03)*Opening hours^2+ 286.67*Group$_1^2$+ 289.83*Group$_2^2$ + 313.79*Group$_3^2$ + (-386.72)*Group$_4^2$ + (-669.20)* Group$_5^2$ + (-557.12)* Group$_6^2$ + 5.16E-04*Volume flow^2*

Supermarket. Total heat (kWh) = 4139102.69 + 13.76*Area + 15194.51*Height + (-462975.81)*T_{in} winter + 2571.90*T_{in} Summer + (-5.26)*Plug in MT + (-6.15)*Plug in LT + (-39.96)*Opening hours + 3808.17*$Group_1$ + 4174.97*$Group_2$ + 5345.12*$Group_3$ + 1851.92*$Group_4$ + 3889.26*$Group_5$ + 5508.50*$Group_6$ + (-9.74)*Volume flow + (-9.22E-04)*$Area^2$ + 1682.40*$Height^2$ + 13116.91*T in $winter^2$+ (-78.34)*T in $Summer^2$+ 2.36E-05*Plug in MT^2 + 4.28E-05*Plug in LT^2 + (-2.39E-04)*Opening $hours^2$+ 27.11*$Group_1^2$+ 34.63*$Group_2^2$ + 122.09*$Group_3^2$ + (-28.20)*$Group_4^2$ + (-7.94)* $Group_5^2$ + 14.35* $Group_6^2$ + 5.89E-05*Volume $flow^2$

Equation 8-3. Total energy representation discount store in Stockholm

Discount Store. Total energy (kWh) = -40101.9 + 198.6*Area + (-14442.1)*Height + 1033.9*T_{in} winter + 10290.6*T_{in} Summer + 5.9*Plug in MT + 9.7*Plug in LT + 3*Opening hours + 3717.8*$Group_1$ + 4371*$Group_2$ + 6827.5*$Group_3$ + 1031.1*$Group_4$ + 8292.7* $Group_5$ + 11871.3*$Group_6$ + (-4.9E-02)*$Area^2$ + 1631.9*$Height^2$ + 120.3*T in $winter^2$+ (233.7)*T in $Summer^2$+ 4.3E-04*Plug in MT^2 + (-1.1E-04)*Plug in LT^2 + 2.7E-03*Opening $hours^2$+ 6.6*$Group_1^2$+ 8.6*$Group_2^2$ + 120.2*$Group_3^2$ + 298.7*$Group_4^2$ + 35.3*$Group_5^2$ + 128.4*$Group_6^2$

Discount Store. Total electricity (kWh) = 10928.22+ 143.30*Area + (-4951.49)*Height + 3890.32*T_{in} winter + 3797.54*T_{in} Summer + 6.90*Plug in MT + 9.12*Plug in LT + (-16.17)*Opening hours + 3013.79*$Group_1$ + 3707.02*$Group_2$ + 6393.43*$Group_3$ + 944.07*$Group_4$ + 8412.95* $Group_5$ + 12633.23*$Group_6$ + (-19.92)*Volume flow + (-1.86E-02)*$Area^2$ + 571.44*$Height^2$ + 33.87*T in $winter^2$+ (-84.05)*T in $Summer^2$+ 1.83E-04*Plug in MT^2 + (-2.08E-05)*Plug in LT^2 + 4.33E-03*Opening $hours^2$+ 87.47*$Group_1^2$+ 86.62*$Group_2^2$ + 158.97*$Group_3^2$ + 345.54*$Group_4^2$ + 47.48*$Group_5^2$ + 13.07*$Group_6^2$+ 3.66E-03*Volume $flow^2$

Discount Store. Total Heating (kWh) = 155338.50 + (-9.33)*Area + 572.63*Height + (-9210.44)*T_{in} winter + (-506.02)*T_{in} Summer + 4.16E-02*Plug in MT + (-0.18)*Plug in LT + 5.26*Opening hours + (-239.42)*$Group_1$ + (-279.49)*$Group_2$ + (-509.36)*$Group_3$ + (-20.24)*$Group_4$ + (-227.53)* $Group_5$ + (-869.21)*$Group_6$ + 4.74E-03*$Area^2$ + (-57.66)*$Height^2$ + 247.71*T in $winter^2$+ 11.62*T in $Summer^2$+ (-1.60E-05)*Plug in MT^2 + 1.77E-05*Plug in LT^2 + (-6.78E-04)*Opening $hours^2$+ 23.92*$Group_1^2$+ 26.85*$Group_2^2$ + 66.04*$Group_3^2$ + 1.93*$Group_4^2$ + 36.56*$Group_5^2$ + 164.12*$Group_6^2$ + 1.12E-03*Volume $flow^2$

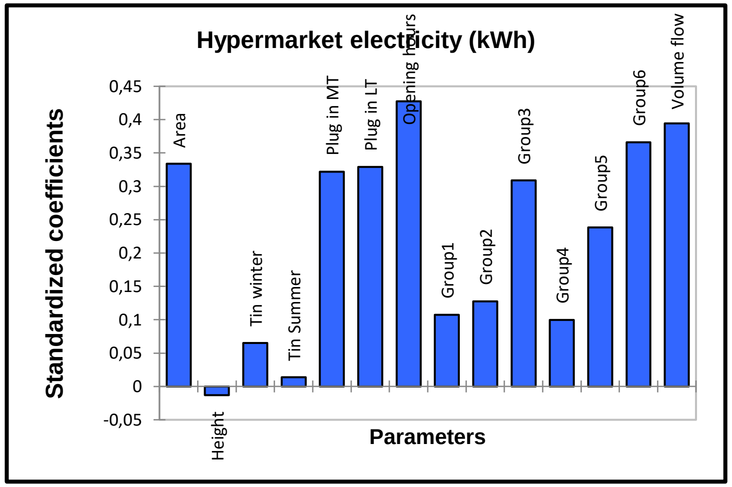
Equation 8-4. Total energy representation convenience store in Stockholm

Convenience store. Total energy (kWh) = -1257505.8 + (-50.2)*Area + 813647.9*Height + 2433.4*T_{in} winter + (-4221)*T_{in} Summer + (-3.4)*Plug in MT + 0.16*Plug in LT + (-7.8)*Opening hours + 5640.8*$Group_1$ + 6020*$Group_2$ + 10621.4*$Group_3$ + 5037.6*$Group_4$ + 10640.2* $Group_5$ + 16766.2*$Group_6$ + (-17.7)*Volume flow + 0.3*$Area^2$ + (-124899.3)*$Height^2$ + 7.3*T in $winter^2$+ 101.1*T in $Summer^2$+ 7.2E-03*Plug in MT^2 + 1.2E-03*Plug in LT^2 + (1.6E-03)*Opening $hours^2$+ 72*$Group_1^2$+ 253.3*$Group_2^2$ + 582.1*$Group_3^2$ + (-112.6)*$Group_4^2$ + 69.9*$Group_5^2$ + (-66.7)*$Group_6^2$ + 1.4E-02*Volume $flow^2$

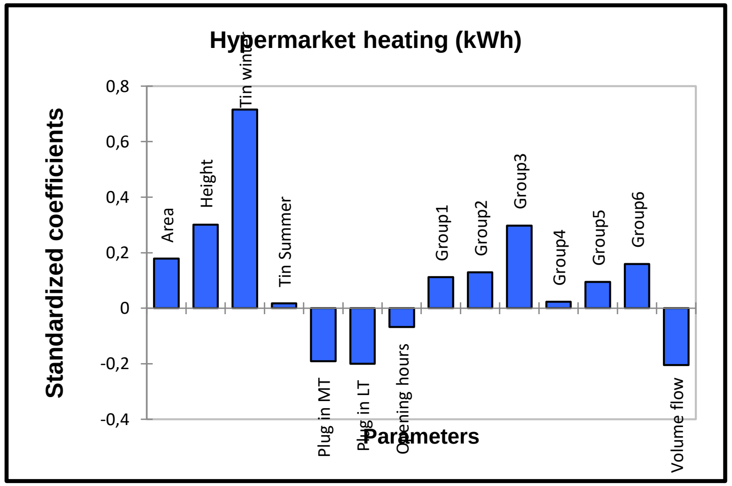
Convenience store. *Total electricity (kWh) = 28820.41 + 142.43*Area + (-7544.01)*Height + (-2753.18)*T_{in} winter + (3740.02)*T_{in} Summer + 12.03*Plug in MT + 8.82*Plug in LT + (-24.67)*Opening hours + 4097.62*$Group_1$ + 5056.72*$Group_2$ + 6251.89*$Group_3$ + 3366.70*$Group_4$ + 6926.34* $Group_5$ + 11273.60*$Group_6$ + (-6.83)*Volume flow + (-2.03E-01)*$Area^2$ + 1005.30*$Height^2$ + 93.56*T in $winter^2$+ (-82.25)*T in $Summer^2$+ (-5.02E-03)*Plug in MT^2 + 4.22E-05*Plug in LT^2 + 4.69E-03*Opening $hours^2$+ (-148.46)*$Group_1^2$+ (-170.53)*$Group_2^2$ + 114.63*$Group_3^2$ + (-80.34)*$Group_4^2$ + 71.03*$Group_5^2$ + (-91.50)*$Group_6^2$ + 9.73E-03*Volume $flow^2$*
Convenience store. *Total heat (kWh) = -4975.20 + 33.14*Area + 824.86*Height + (-560.33)*T_{in} winter + (-9.76)*T_{in} Summer + (-3.32)*Plug in MT + (-6.49)*Plug in LT + (-0.49)*Opening hours + 1772.11*$Group_1$ + 1833.79*$Group_2$ + 4598.47*$Group_3$ + 1242.79*$Group_4$ + 2890.81* $Group_5$ + 4669.60*$Group_6$ + (-1.91)*Volume flow + (-5.57E-03)*$Area^2$ + 12.61*$Height^2$ + 67.37*T in $winter^2$+ 0.12*T in $Summer^2$+ 2.60E-04*Plug in MT^2 + 5.73E-04*Plug in LT^2 + 1.11E-04*Opening $hours^2$+ 191.07*$Group_1^2$+ 281.28*$Group_2^2$ + 438.14*$Group_3^2$ + (-2.16)*$Group_4^2$ + 104.40*$Group_5^2$ + 130.30*$Group_6^2$ + 4.29E-05*Volume $flow^2$*
LINEAR EQUATIONS HEAT RECOVERY
Equation 8-5. Energy factors inside the linear equations for a Hypermarket in Stockholm
Hypermarket. *Total energy (kWh) = -4884176.7 + **156.5***Area + **41193.1***Height + **142377.1***T_{in} winter + **70181***T_{in} Summer + **6.2***Plug in MT + **8.2***Plug in LT + **294.7***Opening hours + **6417.9***$Group_1$ + **7567.2***$Group_2$ + **15695***$Group_3$ + **4153.9***$Group_4$ + **10364.6***$Group_5$ + **16076.8***$Group_6$ + **14.9***Volume flow. ERROR: 0.29%*
Hypermarket. *Total electricity (kWh) = -2361084.6 + **132.3***Area + (**-6045.7**)*Height + **29939***Tin winter + **5159** *Tin Summer + **8.9***Plug in MT + **10.4***Plug in LT + **311.7***Opening hours + **4719.5***Group1 + **5605.7***Group2 + **11760.8***Group3 + **3804***Group4 + **9082.8***Group5 + **13947.2***Group6 + **18.1***Volume flow. ERROR: 0.18%*
Hypermarket. *Total Heat (kWh) = -2568264.4 + **24.3***Area + **47238.7***Height + **112438.1***Tin winter + **2272.5***Tin Summer + **(-1.8)***Plug in MT + **(-2.2)***Plug in LT + **(-16.9)***Opening hours + **1675.8***Group1 + **1938.9***Group2 + **3884.6***Group3 + **300.3***Group4 + **1232.2***Group5 + **2080***Group6 + **(-3.2)***Volume flow. ERROR: 2.98%*
Equation 8-6. Energy factors inside the linear equations for a Supermarket in Stockholm
Supermarket. *Total energy (kWh) = -1829716 + **123.3***Area + **30951***Height + **64773.8***T_{in} winter **- 465.8***T_{in} Summer + **5.3***Plug in MT + **5.9***Plug in LT + **43***Opening hours + **12258***$Group_1$ + **13886***$Group_2$ + **22847.8***$Group_3$ + **4561.3***$Group_4$ + **12292.3***$Group_5$ + **18041.4***$Group_6$ + **11.7***Volume flow.*

Supermarket. *Total electricity (kWh) = -1028965.4 + **116***Area + (**-1310.1**)*Height + **19433.3***Tin winter + **252.6***Tin Summer + **10***Plug in MT + **11.5***Plug in LT + **97.7***Opening hours + **7528.2***Group1 + **8533.7***Group2 + **13351.5***Group3 + **3047.8***Group4 + **8498.3***Group5 + **12360.7***Group6 + **17.6***Volume flow. ERROR: 0.65%*
Supermarket. *Total Heat (kWh) = -867503.1 + **7.3***Area + **31919.9***Height + **45613.5***Tin winter + (**-718.3**)*Tin Summer + (**-4.4**)*Plug in MT + (**-5.3**)*Plug in LT + (**-41.9**)*Opening hours + **4729.9***Group1 + **5352.4***Group2 + **9496.3***Group3 + **1513.6***Group4 + **3794***Group5 + **5680.7***Group6 + (**-5.9**)*Volume flow. ERROR: 3.97%*
Equation 8-7. Energy factors inside the linear equations for a discount store in Stockholm
Discount Store. *Total energy (kWh) = 162947.4 + **108.3***Area + (**-840.5**)*Height + **5610***T_{in} winter + **597.4***T_{in} Summer + **6.9***Plug in MT + **8.7***Plug in LT + **21***Opening hours + **3793***$Group_1$ + **4461.6***$Group_2$ + **7743.5*** $Group_3$ + **3141.3*** $Group_4$ + **8507.8***$Group_5$ + **12756.5*** $Group_6$ + **22.8***Volume flow.*
Discount Store. *Total electricity (kWh) = -189750.9 + **108.9***Area + (**-807.8**)*Height + **5439.5***Tin winter + **568.9***Tin Summer + **7***Plug in MT + **8.8***Plug in LT + **21.7***Opening hours + **3825.2***Group1 + **4512.1***Group2 + **7733.9***Group3 + **3191.6***Group4 + **8516.3***Group5 + **12489***Group6 + **24***Volume flow. ERROR:* 0.27%
Discount Store. *Total Heat (kWh) = 26803.5 + (**-0.57**)*Area + **32.7***Height + **170.5***Tin winter + **28.5***Tin Summer + (**-6.7E-02**)*Plug in MT + (**-5.7E-02**)*Plug in LT + (**-0.7**)*Opening hours + (**-32.2**)*Group1 + (**-50.6**)*Group2 + **9.6***Group3 + (**-50.3**)*Group4 + (**-8.5**)*Group5 + **267.5***Group6 + (**-1.2**)*Volume flow. ERROR:* 1.62%
Equation 8-8. Energy factors inside the linear equations for a convenience store in Stockholm
Convenience Store. *Total energy (kWh) = 148454.3 + **78.6***Area + (**-63355.2**)*Height + **2334.8***T_{in} winter + **346.2***T_{in} Summer + **2.9***Plug in MT + **4.8***Plug in LT + **2.4***Opening hours + **6554.5***$Group_1$ + **7951.6***$Group_2$ + **14007.5***$Group_3$ + **4138.9***$Group_4$ + **10551.5***$Group_5$ + **16015.4***$Group_6$ + **10.8***Volume flow.*
Convenience Store. *Total electricity (kWh) =* -9170.7*+ **48.1***Area + (**-615.3**)*Height + **550.6***Tin winter + **315***Tin Summer + **6.1***Plug in MT + **9***Plug in LT + **2***Opening hours + **3108.7***Group1 + **4158.1***Group2 + **6538***Group3 + **2888.6***Group4 + **7177.3***Group5 + **10736.8***Group6 + **12.6***Volume flow. ERROR: 1%*
Convenience Store. *Total Heat (kWh) =* -32254.9 *+ **30.6***Area + **714.6***Height + **1765.2***Tin winter + **50.2***Tin Summer + (**-3.3**)*Plug in MT + (**-4.2**)*Plug in LT + **0.3***Opening hours + **3436.6***Group1 + **3799.1***Group2 + **7460.3***Group3 + **1237.8***Group4 + **3358.2***Group5 + **5262.5***Group6 + (**-1.8**)*Volume flow. ERROR: 5.97%*

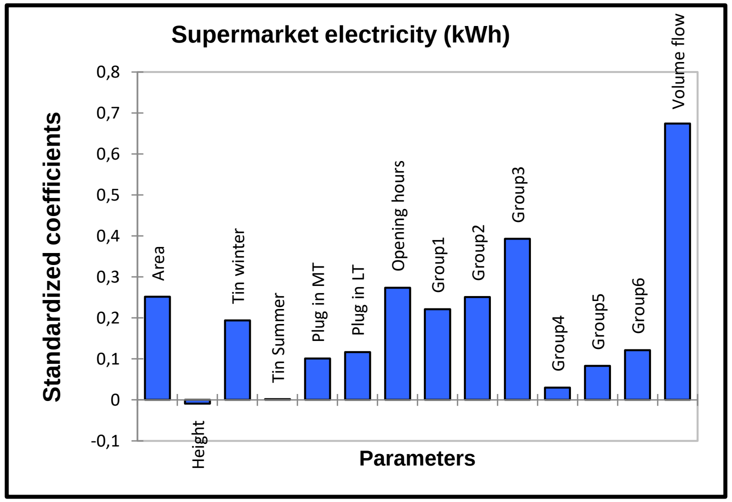
Annex 8-18. Resume of all the equations for heat recovery refrigeration technology.



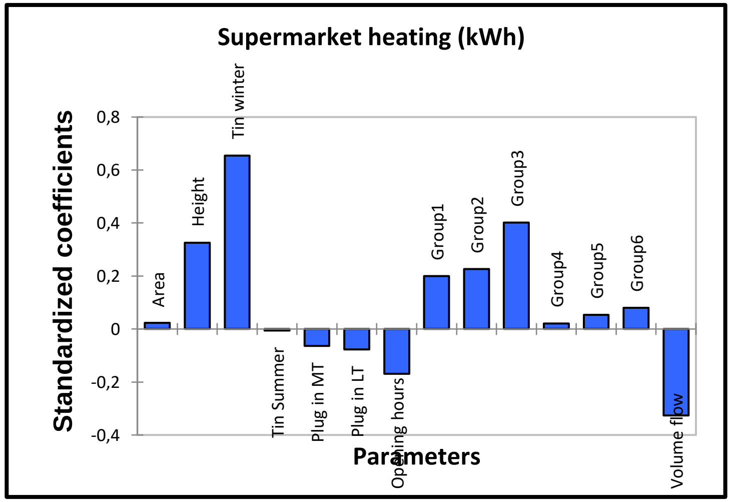
Annex 8-20. Hypermarket Standardized coefficients for the electricity linear regression. Heat recovery technology.



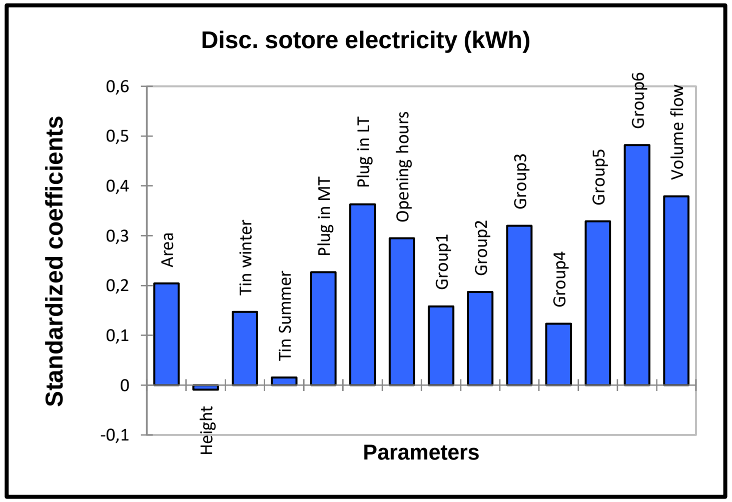
Annex 8-19. Hypermarket Standardized coefficients for the heating linear regression. Heat recovery technology.



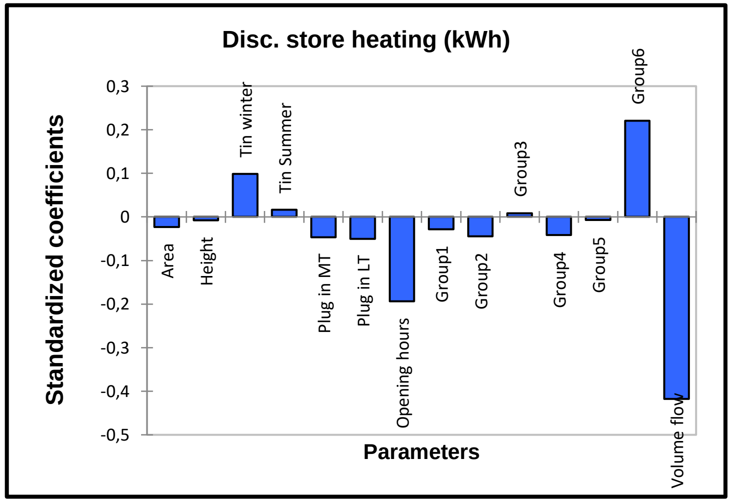
Annex 8-22. Supermarket Standardized coefficients for the electricity linear regression. Heat recovery technology.



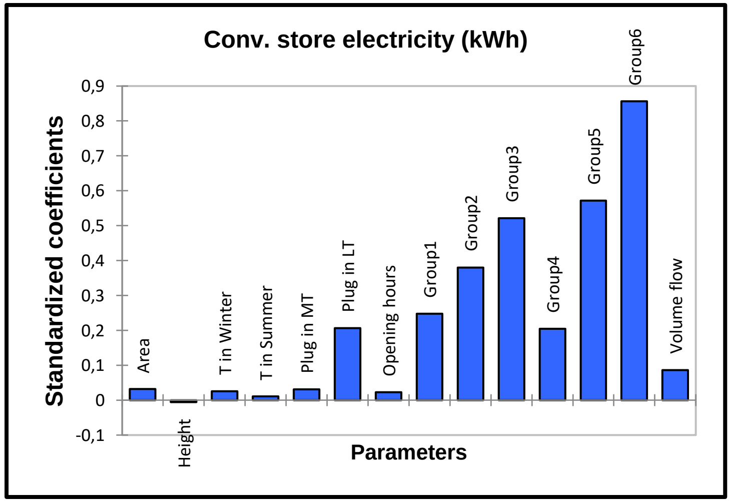
Annex 8-21. Supermarket Standardized coefficients for the heating linear regression. Heat recovery technology.



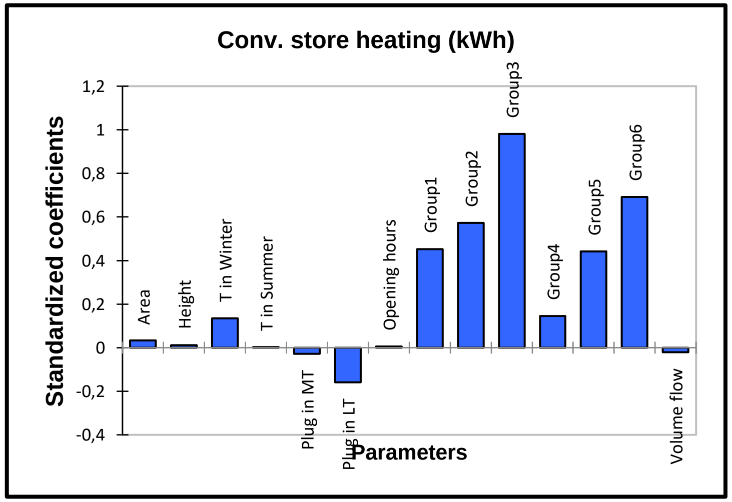
Annex 8-23. Disc. Store Standardized coefficients for the electricity linear regression. Heat recovery technology.



Annex 8-24. Disc. Store Standardized coefficients for the heating linear regression. Heat recovery technology.



Annex 8-25. Conv. store Standardized coefficients for the electricity linear regression. Heat recovery technology.



Annex 8-26. Conv. store Standardized coefficients for the heating linear regression. Heat recovery technology.

Temperature (°C)	COP_LT_CO2	COP_MT_CO2	COP_AC_R410A	COP_AC_CO2	COP_HR_CO2	COP_HR_HFC_ASHP	COP_HR_HFC_GSHP	COP _DHW
-20	2,53	7,39	No use	No use	3,636	0,95	3,531	5,4
-19	2,53	7,39	No use	No use	3,682	0,95	3,536	5,4
-18	2,53	7,39	No use	No use	3,73	0,95	3,541	5,4
-17	2,53	7,39	No use	No use	3,782	0,95	3,546	5,4
-16	2,53	7,39	No use	No use	3,837	0,95	3,552	5,4
-15	2,53	7,39	No use	No use	3,898	0,95	3,557	5,4
-14	2,53	7,39	No use	No use	3,963	0,95	3,562	5,4
-13	2,53	7,39	No use	No use	4,034	0,95	3,567	5,4
-12	2,53	7,39	No use	No use	4,112	0,95	3,572	5,4
-11	2,53	7,39	No use	No use	4,197	0,95	3,578	5,4
-10	2,53	7,39	No use	No use	4,292	1,628	3,583	5,4
-9	2,53	7,39	No use	No use	4,398	1,756	3,588	5,4
-8	2,53	7,39	No use	No use	4,537	1,912	3,593	5,4
-7	2,53	7,39	No use	No use	4,596	2,108	3,598	5,4
-6	2,53	7,39	No use	No use	4,567	2,364	3,603	5,4
-5	2,53	7,39	No use	No use	4,471	2,715	3,609	5,4
-4	2,53	7,39	No use	No use	4,338	2,838	3,614	5,4
-3	2,53	7,39	No use	No use	4,187	2,961	3,619	5,4
-2	2,53	7,39	No use	No use	4,029	3,085	3,624	5,4
-1	2,53	7,39	No use	No use	3,876	3,211	3,628	5,4
0	2,53	7,39	No use	No use	3,732	3,572	3,863	5,4
1	2,53	7,39	No use	No use	3,583	3,71	3,868	5,4
2	2,53	7,39	No use	No use	3,455	3,852	3,873	5,4
3	2,52	7,34	No use	No use	3,348	3,998	3,878	5,4
4	2,52	7,28	No use	No use	3,264	4,147	3,883	5,4
5	2,51	7,22	No use	No use	3,221	4,301	3,887	5,4
6	2,50	7,16	No use	No use	3,385	4,461	3,891	5,4
7	2,49	7,06	No use	No use	3,651	4,627	3,895	5,4
8	2,42	6,64	No use	No use	4,096	4,799	3,898	5,4

9	2,36	6,25	No use	No use	4,907	4,98	3,901	5,4
10	2,30	5,90	No use	No use	6,703	5,169	3,902	5,4
11	2,25	5,60	6,32	4,94	No use	No use	No use	5,4
12	2,19	5,30	6,03	4,66	No use	No use	No use	5,4
13	2,10	5,20	5,77	5,78	No use	No use	No use	5,4
14	2,05	4,94	5,53	5,43	No use	No use	No use	5,4
15	2,00	4,70	5,30	5,11	No use	No use	No use	5,4
16	1,95	4,48	5,09	4,80	No use	No use	No use	5,4
17	1,90	4,26	4,90	4,52	No use	No use	No use	5,4
18	1,85	4,06	4,72	4,24	No use	No use	No use	5,4
19	1,81	3,87	4,55	3,98	No use	No use	No use	5,4
20	1,76	3,68	4,39	3,73	No use	No use	No use	5,4
21	1,71	3,50	4,24	3,60	No use	No use	No use	5,4
22	1,66	3,33	4,09	3,47	No use	No use	No use	5,4
23	1,61	3,16	3,96	3,35	No use	No use	No use	5,4
24	1,56	3,00	3,83	3,24	No use	No use	No use	5,4
25	1,50	2,83	3,71	3,12	No use	No use	No use	5,4
26	1,44	2,65	3,59	3,02	No use	No use	No use	5,4
27	1,39	2,50	3,48	2,93	No use	No use	No use	5,4
28	1,34	2,37	3,38	2,84	No use	No use	No use	5,4
29	1,29	2,24	3,28	2,67	No use	No use	No use	5,4
30	1,25	2,13	3,18	2,53	No use	No use	No use	5,4
31	1,21	2,03	3,09	2,39	No use	No use	No use	5,4
32	1,17	1,93	3,00	2,26	No use	No use	No use	5,4
33	1,13	1,85	2,92	2,15	No use	No use	No use	5,4

Annex 8-27. Highest COP's for each energy sub-system.

Establishment	Total area [m2]	Optimum Case [kWh/year*m^2] (primary energy)	CyberMart Case using floating condensing technology [kWh/year*m^2] (primary energy)	Difference [%]
Hypermarket	11600	956	1058	9.7
Supermarket	3500	984	1174	16.2
Disc. Store	924	975	1084	10
Conv. Store	232	702	795	11.7

Annex 8-28. Results using floating condensing technology and 2.5 and 1.0 as primary energy factors.

Establishment	Total area [m2]	Optimum Case [kWh/year*m^2] (primary energy)	CyberMart Case using heat recovery technology [kWh/year*m^2] (primary energy)	Difference [%]
Hypermarket	11600	612	692	11.6
Supermarket	3500	630	778	19.0
Disc. Store	924	624	752	17.0
Conv. Store	232	449	521	13.8

Annex 8-29. Results using heat recovery technology and 1.6 and 1.0 as primary energy factors.

Establishment	Total area [m2]	Optimum Case [kWh/year*m^2] (primary energy)	CyberMart Case using floating condensing technology [kWh/year*m^2] (primary energy)	Difference [%]
Hypermarket	11600	612	701	12.8
Supermarket	3500	630	801	21.3
Disc. Store	924	624	736	15.3
Conv. Store	232	449	521	13.7

Annex 8-30. Results using floating condensing technology and 1.6 and 1.0 as primary energy factors.